Attachment I
SWIFT Research Center: NWRI Panel and Academic Review of UIC Inventory Information Package

A T T A C H M E N T I

SWIFT Research Center SWIFT Research Center: NWRI Panel and Academic Review of UIC Inventory Information Package

Prepared for

United States Environmental Protection Agency

Revision Date December 2017

Sustainable Water Initiative for Tomorrow

Contents

NWRI National Water Research Institute

Date: November 21, 2017

To: J. Dano, P.E., Project Manager, Hampton Roads Sanitation District

From: Glen Daigger, Ph.D., Chair of the NWRI Independent Panel for Hampton Roads Sanitation District's Sustainable Water Initiative for Tomorrow (SWIFT) Project

Kevin M. Hardy, Executive Director, National Water Research Institute

Subject: Comments on the Underground Injection Control (UIC) Inventory Information Package for Hampton Roads Sanitation District's (HRSD) Sustainable Water Initiative for Tomorrow (SWIFT) Project

---

The National Water Research Institute (NWRI) is pleased to provide this memorandum prepared by the NWRI Independent Advisory Panel (Panel) for the Hampton Roads Sanitation District's (HRSD) Sustainable Water Initiative for Tomorrow (SWIFT) Project. The focus of this memorandum is the Panel's comments on the "Underground Injection Control (UIC) Inventory Information Package" for HRSD's SWIFT Project, which HRSD provided to the Panel for review on October 17, 2017.

The Panel would like to acknowledge the past service of their friend and colleague, Thomas Grizzard, who passed away in June of 2017. The Panel also would like to collectively welcome new member Jeffrey Mosher of the Water Environment and Reuse Foundation (WE&RF). An updated summary of Panel member biographies is provided in Attachment A.

Panel Comments on the UIC Inventory Information Package

The Panel appreciated the opportunity to review the information package for the UIC permit, and feels that the information is generally well-written and organized effectively. The table provided on pages 3-11 of this memo contains the Panel's general comments and recommendations specific to each of the seven documents the Panel reviewed, which are listed below.

1) Underground Injection Control Inventory Information Package
2) Attachment B: SWIFT Research Center Finished Water Quality Targets
3) Attachment C: SWIFT Research Center Monitoring and Contingency Plans
4) Attachment D: Geochemical Evaluation and Framework Development
5) Attachment E: Plan for Evaluating SWIFT Soil Aquifer Treatment
6) Attachment G: SWIFT Research Center HACCP Memo
7) Attachment H: SWIFT Advanced Water Treatment Pilot Data Review

National Water Research Institute
18700 Ward Street, Fountain Valley, CA 92708
(714) 378-3278 • Fax: (714) 378-3375
www.NWRI-USA.org

Kevin M. Hardy
Executive Director
khardy@NWRI-USA.org

NWRI Panel for the HRSD SWIFT Project

Panel Review of Documents for the SWIFT Research Center
Underground Injection Control Inventory (UIC) Information Package

GENERAL Comments	
0-1	The documents in this review package were apparently produced over a period of time, some at least several months prior to this review. For example, Appendix G is dated June 7, 2017, while Appendix E was apparently produced some time ago as it presents significant actions in the future tense ("to be completed") that already have been initiated or completed per the schedule of events included in the document. Of the documents provided, only Appendix G is dated, which creates confusion from a reviewer's perspective to understand the actual current status of the information presented, what decisions have been made, and when. Each document should contain a register summarizing the sequence of issuance and review steps so that the history of development is clear. Given the evolutionary development of the material provided, a statement is needed, perhaps in the "Inventory Information Package," explaining that the information provided is current as of the date of submission of the information package.
Document 1. Underground Injection Control Inventory Information Package	
1-1	Page 7, last paragraph in the first section, third sentence. This sentence appears to have a missing word, as "from the recharge well, until approximately 100 days." Page 7, "Piloting Advanced Treatment Processes," third sentence. Parameters do not think. The Panel suggests "considering other parameters that may become of concern in the future."
1-2	What evidence exists that pretreating the aquifer to only a 20-foot radius will be sufficient to control clay swelling? Because the estimated travel time is 1 week to the first monitoring well, which is located 50 feet away, it is advisable to consider increasing the pre-treatment radius. Note that if clay swelling does occur, it is not reversible.
Document 2. Attachment B: SWIFT Research Center Finished Water Quality Targets	
2-1	Page 2, Process Design Summary. The statement that "the higher TOC concentration present in the pilot effluent from the carbon train does not equate to a higher human health risk," which is based only on the lack of endocrine or cytotoxic response in the respective bioassays, is not strictly true. Total organic carbon (TOC) is a precursor to disinfection byproducts, which are not measured by the bioassays. The higher the TOC, the higher the tendency to form total trihalomethanes (TTHM) and haloacetic acids (HAA5); hence, the higher human health risk. It would certainly be possible to modify the subject statement to clarify this point, but it could lead to further confusion. The Panel suggests that HRSD remove the statement that "the higher TOC concentration present in the pilot effluent from the carbon train does not equate to a higher human health risk" and instead define the target TOC level and indicate whether the treated water met this target value.

2-2	Page 3, Table 1: The total number of quantified emerging contaminants is listed in the table as 13 for both the Pilot Carbon train and Pilot Membrane train. It is not a correct accounting for the total detections of chemicals of emerging concern (CECs) because the table on page 71 of Attachment H lists only the number of detected CECs per sampling date without identifying them; therefore, by summing the number of detected CECs from the eight sampling dates, which most likely included several of the same types of CEC, the total number of CEC includes multiple counts of many types of CECs. In other words, if the only detected CEC during all eight sampling events was carbamezapine, the table would report eight total CECs when in fact there was only one CEC detected (i.e., carbamezapine). The tables should be corrected to identify the types of CECs detected at each sampling date and the total number of types of CECs. It is important to not count each CEC multiple times.
2-3	Page 3, Table 1: Clarify why the Primidone concentration in the carbon train effluent is reported as a range (and it is a very narrow range: <0.005 to 0.0052 micrograms per liter (µg/L)). Is the range the detection limits? For instance, the Primidone concentration reported for the membrane train was < 0.005 µg /L, so it should be reported as non-detect. It is confusing why the detection limit in the carbon train is not the same as in membrane train. Also, it is unlikely that the analytical method is capable of distinguishing between 0.005 µg /L and 0.0052 µg /L.
2-4	Page 2, Table 1: It is not apparent from the data presented in the report that the 99th percentile values for total coliform and *E. coli* are <1 MPN/100 mL for both treatment trains because no more than 60 samples were analyzed. A larger number of analyses is needed to describe tendencies and upper-bound performance. Please explain how these values were determined.
2-5	Page 6: The coagulation, flocculation, and sedimentation processes can effectively reduce pathogens in water, especially if the process is optimized for performance. Process optimization for pathogen reduction is encouraged. Efforts to associate pathogen reduction with other process performance indicators for operational monitoring, such as turbidity or particle count reduction, are potentially useful process monitoring parameters and can be encouraged for consideration. However, there is no critical control point (CCP) for coagulation-flocculation and sedimentation. The Panel would find it helpful to know the process for monitoring and validating the performance of coagulation, flocculation, and sedimentation. Consider adding a CCP validation parameter for this treatment process if a practical one can be identified.
2-6	Page 6, Biofiltration: It is not clear that biofiltration will achieve appreciable pathogen log reduction values (LRVs), especially for viruses, unless designed for and operated under conditions that will provide sufficient biological activity and contact time for viruses to be effectively removed and/or inactivated. Most granular media filters are poor at virus removal and inactivation without chemical pre-treatment by coagulation, unless operated to promote biological activity at a slow flow rate (as in slow sand filtration). Biofiltration should be optimized and its performance better characterized for pathogen reductions if HRSD will seek LRV credits for this process. Current data for pathogen reduction has a wide range of LRVs, so a more accurate determination of LRVs based on central tendency and 95-percent confidence limit (CL) is encouraged. Efforts to associate with other performance indicators for operational monitoring is encouraged.

2-7	Page 7, Table 2: The Panel supports the use of a "small side stream of the SWIFT Water (1 to 2 gallons per minute) will be periodically pumped to a flow-through tank, free chlorinated, and made available for consumption during tasting events held at the SWIFTRC." Is regulatory approval needed for this activity?
2-8	Page 7, Table 2: Note that the required free chlorine contact time and concentration (CT) value of 4.8 milligram-minutes per liter (mg/L-min) may not be sufficient to achieve the target LRV of 4 for the Chlorine Concentrations x Contact Time (CT) Virus Log Removal Value (if free chlorine disinfection is practiced). Some enteric viruses, such as *Coxsakievirus*, may require a much larger CT value, perhaps by a factor of 5 or more, depending on temperature, pH, and other water quality conditions. Further consideration of this target CT value is advised. If chlorination will be an important barrier for this application, then choose an appropriate CT value from the literature that is protective of public health and does not compromise the tasting specifications.
2-9	Page 8 and beyond: Comment 2-9 (this comment) has ramifications throughout this documents and others. It appears HRSD has proposed an adaptive management approach to establish LRV credits for soil aquifer treatment (SAT) consisting of soil column tests (in progress at the time of the preparation of these comments) at the York River Treatment Plant, followed by other activities yet to be defined to be conducted using soil columns at the Nanesmond Demonstration Plant. It also appears that HRSD is prepared to adjust the demonstration plant advanced treatment train, if necessary, pending resolution of the credits obtainable through SAT. While the Panel is supportive of this approach, the Panel can only comment, based on the initial steps (soil column testing at York River), that the adaptive management approach appears appropriate; however, further steps are likely and have yet to be detailed and appropriately reviewed. The Panel requests that HRSD either (a) confirm the Panel has articulated HRSD's overall adaptive management approach correctly, or (b) explain HRSD's management approach if the Panel's understanding is not correct. The Panel also suggests that the approach be clearly and succinctly articulated in all relevant documents in this review package.
2-10	Page 8, Paragraph 1: What is the purpose of defining LRVs in the subsurface? Will HRSD adjust the treatment train based on these definitions? If so, caution is recommended in trying to estimate virus reductions in subsurface aquifers based on modelling estimates of other parameters, as such modelling is known to be inaccurate in many cases. *In situ* virus monitoring may be a better predictor of virus reduction than travel time and reductions of other water quality parameters. Soil column studies also may not provide reliable information on virus reduction in aquifers, especially if done with disturbed soil materials packed into columns. Soil column studies are worthwhile if performed with the material present in the subsurface of the project site, but the data generated may not be representative of actual aquifer conditions and virus reduction performance *in situ*. The column test is a reasonable first step, and the Panel suggests *in situ* testing if an analysis of the data suggests that additional data is needed to refine the estimates. The motivation for and intended use of the soil aquifer LRV estimates should be clear, especially if it will influence the choice of the reclaimed water treatment train.
2-11	Page 10, Table 5: • Non-regulatory performance indicators are listed, which were chosen based on several criteria, including high occurrence in wastewater treatment plant (WWTP) effluent; however, the performance indicators should include Iohexal, based on its high frequency of occurrence and non-removal in various treatment processes. For instance, Iohexal was detected after treatment by Ozone, BAC1, BAC2, GAC1, and RO, as shown in page 72 of Attachment H.

	• The Panel supports the concept of non-regulated performance indicators. What was the process for determining values in Table 5 for 17-β-Estradiol and ethinyl estradiol? • The rational and source of the values in Table 5 should be provided.
2-12	Page 11, Table 6: It is advisable to narrow the range of performance for biological activated carbon (BAC). A range of zero to three (0-3) log removal is too variable and uncertain. An effort should be made to better specify the expected LRV based on actual performance data from lab- and pilot-scale studies to determine average and range of LRVs as 95%-percent CLs. The Panel recognizes that HRSD will be gathering data to respond to this comment.
2-13	Page 11, Table 6: It is advisable to obtain better data on the extent of virus removal by ozone because a 0-3 log reduction range has high variability and uncertainty that can be reduced. This variability may be reduced to develop a more precise estimate of ozone LRV, with mean and median values and 95-percent CLs. Further studies are recommended to address this matter. The Panel recognizes that HRSD will gather data to respond to this comment.
2-14	Page 11, UV dose: Will the UV reactor be validated on site?
2-15	The lack of LRV credit for viruses, *Cryptosporidium,* and *Giardia* by BAC-GAC is questionable and needs further documentation. BAC may be able to reduce viruses and protozoan parasites to some extent, depending on operating conditions, because other biological processes can reduce enteric viruses and protozoan parasites; therefore, under some design/operating conditions, BAC may achieve measurable LRV reductions. Are BAC LRVs being sought? If such LRV are refined based on new data, how will these data be used in managing this treatment process?
2-16	Page 12: To receive credit for TOC reduction through SAT and to modify the TOC regulatory limit at the wellhead accordingly, HRSD will need to: 1) conduct a modelling study each well or well field to confirm travel times; and have monitoring requirements at monitoring wells to verify the water quality.
2-17	Page 12, Table 7: For tasting events, how will HRSD ensure LRVs of at least 10 for protozoa? The predicted range is 8 to 12.
2-18	Page 17, Table 10: What is the basis for the frequency of protozoan parasite and *Legionella* monitoring being only quarterly? More frequent analysis would be advisable, perhaps monthly.
2-19	Page 26, Table 10: It is advisable to increase the sampling frequency of coliphages from monthly to weekly. The analysis of coliphages as fecal indicator viruses is easy, fast, and economical.
2-20	For CCPs, see Comment 6-1 (for Attachment G).
Document 3. Attachment C: SWIFT Research Center Monitoring and Contingency Plans for Managed Aquifer Recharge	
3-1	For monitoring wells, the analytical schedule appears to anticipate two phenomena occurring in the aquifer, namely advection/dispersion and attenuation. But, the third phenomenon is acclimation, especially for biologically mediated transformations. The analytical protocols should anticipate acclimation, especially for biologically mediated constituents, but also potentially for others.

3-2	It appears that injection will occur in a single well into three zones. How will the flow be assessed for each zone? There will be a tendency for all the flow to enter the zone with the highest hydraulic conductivity.
3-3	On Pages 1-2, the conditioning distance states “20 to 50 feet radius,” which is different from the information in Document 1. Which distance is correct?
3-4	Page 1-4, Figure 1-2: Monitoring well MW-SAT is mislabeled.
3-5	As written, “well construction” is in the future tense; however, a table listing the depths and screen lengths of the 11 screens at TW-1 and corresponding data at MW-SAT is recommended. Also, the depths in Figures 1-3 and 1-4 are difficult to read.
3-6	Page 1-10, Section 1.3: It states that wells MW-UPA and MW-MPA contain four screens each; however, the diagrams in Figure 1-7 show two screens for MW-UPA and three screens for MW-MPA.
3-7	Page 1-10, Section 1-3: Sampling of the conventional monitoring wells using a single pump per well suggests that groundwater will be derived from multiple screens, resulting in a mixed chemical signature at each well. The use of a dedicated packer system to isolate well screens is recommended.
3-8	The monitoring of phosphate should be considered during operation. Biofilm formation in aquifer systems may be phosphate-limited and could occur in this injection system. Biofilms, once started, are difficult to remove and lead to aquifer clogging.
3-9	Please add an explanation as to how air bubbles in the injection water will be limited, because air impaction causes rapid rates of injectivity decline.
3-10	Page 2-23, Section 2.3.1: Chloride is identified as a tracer when, in fact, the absence of chloride serves as a "reverse tracer." Conceptually, it means a breakthrough of recharge water will result in a reduction of chloride concentration. The opposite is shown in Figure 2-5.
3-11	Monitoring chloride concentration reduction as an indication of physical transport may work reasonably for MW-SAT (50-foot radial distance), but will be subject to significant uncertainty in zones where lower hydraulic conductivity increases travel time. Back-diffusion and mixing of chloride from lower-permeability materials in contact with the aquifer materials (interbedded or adjacent) is a concern. Also, at the more distant wells (e.g., MW-UPA), this approach may not produce definitive data.
3-12	Page 2-23, Section 2.3.1: The Hach Quantab may be a reliable test for chloride ion concentrations in the field, but the accuracy is questionable. The test strips for 30 to 600 chloride Cl- are limited to increments of 10-20 parts per million.
3-13	Page 2-23, Section 2.3.2: Recharge will not be even across all 11 screens based on the known heterogeneity of the aquifer. There will be considerable differences in unit injectivity. How will this be monitored? The periodic running of a dynamic flowmeter log during operation could be a means of measuring the variability of flow to the three zones.
3-14	Page 2-24, Section 2.3.2: The travel time evaluation in each sand interval screened requires precise inflow measurements. How will the inflow be monitored at each open aquifer in the well?

3-15	Page 2-24, Section 2.3.3: Regarding the issue of injection rate into multi-zonal screened wells, there is always a preferential flow rate into the uppermost screened interval with a progressive downward loss of driving head. The head loss in the first screened interval causes the driving head to be lower in the next lower screened increment. In-well flow metering during injection could be used to measure the flow rates during operation. If the flow rates are not known, then all the coefficients estimated from the breakthrough curves will be incorrectly calculated.
3-16	Section 2.3.3: The method of analyzing breakthrough curves is not provided. What method(s) will be used? This comment applies for other constituents and not just tracers.
3-17	Page 2-25, Section 2.3.5: The sampling interval for chloride and conductivity is given as 12 hours. This sampling interval may not produce definitive reserve breakthrough curves. Increasing the frequency is recommended.
3-18	Page 3-1, Section 3.1.1: Injectivity loss may occur due to the process of reversing flow through the gravel pack during cleaning cycles. The loss can be corrected by redeveloping the well using compressed air and/or water surging with a packer. The screen and gravel pack design is rarely applied to a pumping well with unidirectional flow because injection wells tend to push the coarser gravel away from the screens and can cause mixing with finer material. This mixing also occurs when the wells are flushed during cleaning. The issue of bi-direction flow has not been resolved and will ultimately cause require redevelopment.
Document 4. Attachment D: Geochemical Evaluation and Framework Development for the SWIFT Proposed Managed Aquifer Recharge Program	
4-1	Page 2-2, Table 2-1: The Panel suggests adding “Gravel pack disruption” to the list of potential issues.
4-2	Page 2-2: Note that nitrate is also an oxidizing agent that can affect mineral dissolution.
4-3	Page 3-2 to 3-3, Table 3-2: Should nitrate also be included in this table?
4-4	Section 5: Oxygen concentration in the injected water is not the only potential cause of dissolution and mobilization of various cations; rather, the overall oxidation potential of the water is significant. Arsenic mobilization has been observed in water that contains no dissolved oxygen, but has a high oxidation potential.
4-5	Section 6.3.1: A description is provided of the use of monitoring well MW-LPA to test effectiveness of a hydroxy-aluminum chloride flush and develop protocols before treating test well TW-1. Given the approaching start date (April 2018), when will this analysisbe completed, and how will it be incorporated into decision-making, both in the short term and in conjunction with the pilot test and in the long term?
Document 5. Attachment E: Plan for Evaluating SWIFT Soil Aquifer Treatment	
5-1	What porosity is assumed for the soil columns? This information is important, as many calculations are based on this assumption.
5-2	How representative is pathogen testing on the soil columns prior to establishing the biological and chemical reactions that will be present in the aquifer? What logic is this based on? Bsed on this logic, what over-estimates or under-estimates of log removals could result?

5-3	Construction and initial operation of the columns have already occurred. It is confusing and misleading, as the document is not dated and presents several events that have already occurred as if they will occur in the future. The text should be adjusted to be representative of the actual sequence of events. If this document was completed in the first half of 2017, it should be indicated. Note that a review by the Panel earlier in the process would have produced more useful feedback to HRSD.
5-4	What is the source of Potomac Aquifer System (PAS) sand used in the Phase I SAT Column testing?
5-5	If a clear plastic PVC pipe or glass is used, the outside of the column pipe should be painted black (fabric is not as effective in removing all light wavelengths) to avoid the growth of light-sensitive organisms within the column media, which could invalidate the results of the column study. Also, to avoid air entrapment in the column, the column should initially be flooded from the bottom upwards. One column should be run as a control without the addition of chlorine or dissolved oxygen to assess true unassisted pathogen removal (see Dehwah, A.H.A, and Missimer, T.M., 2017, Seabed gallery intakes: Investigation of the water pretreatment effectiveness of the active layer using a long-term column experiment: Water Research, v. 121, p. 95-108, Doi: 10.1016/j.water2017.05.014.) http://repository.kaust.edu.sa/kaust/handle/10754/623684
5-6	The inflow water quality samples should be collected from the inflow pipe at the top of each column and not from a common feeder tank or reservoir. Variations in microorganism concentration commonly occur with feeder tanks.
5-7	Page 3-10, Table 3-3: The Panel suggests adding orthophosphate and total phosphorous to the table.
5-8	The Panel suggests that HRSD review the column research conducted on trace contaminants by Mazahirali Alidina, Jörg Drewes, and Christaine Hopp-Jones. HRSD should take great care in the final design of the column tests because many errors have been made in the test design, which can raise scientific questions concerning the validity of the results.
5-9	Section 3.1, first bullet: Evaluate the removal of pathogens and pathogen indicators by SAT, with specific focus on confirming at least 1-log removal of viruses, *Cryptosporidium*, and *Giardia* per month of aquifer travel time. Note that California allows credit for 6-log removal after 6 months of travel time for *Cryptosporidium* and *Giardia* only; the 1-log removal per month value is for viruses only.
5-10	Section 3: Are fluorescent microspheres being used in place of *Cryptosporidium* and *Giardia*? It is not clear. If this technique is to be used, the characteristics of the microspheres must mimic those of *Cryptosporidium* and *Giardia* cysts and oocysts.
5-11	Section 3: Several tables (3.3., 3.4, 3.5) are numbered incorrectly.
Document 6. Attachment G: SWIFT Research Center HACCP Memorandum	
6-1	"CCP" should be defined in the memo to underscore that it is a unit process where risk can be reduced, and that monitoring controls exist. The definition from WRRF-15-01[1] is "A CCP is a point in the treatment train (i.e., a unit treatment process) that is designed specifically to reduce, prevent, or eliminate a human health hazard and for which controls exist to ensure the proper performance of that process."

[1] Potable Reuse Research Compilation: Synthesis of Findings, Prepared by the National Water Research Institute for the Water Environment & Reuse Foundation, Virginia. Published 2016. Project Number: Reuse-15-01.

6-2	Page 20, Table 2.10: It is not clear if the influent pump station (IPS) can be a CCP. What is the meaningful reduction in risk provided by the IPS? The pump station should probably be a monitoring point. The Panel understands that monitoring for nitrate at the IPS is a "control." Should CCPs be allowed for the processes that do not reduce risk, but just identify the potential for risk?
6-3	Table 2.9: Please explain the process for monitoring for ozone CCPs.
6-4	Table 2.9: For GAC, how will performance be assessed just by monitoring the effluent TOC?
6-5	Table 2.10: Conductivity is listed as a parameter for the IPS. How does conductivity at the IPS control for nitrate, nitrite, pathogens, and DBP precursors?
6-6	Table 2.10: It is not clear that conductivity, turbidity, and nitrogen testing at the IPS constitutes a CCP. Although these parameters should be monitored and alarms should exist, the CCPs should be something very specific to risk reduction. The monitoring proposed for these parameters seems like an operational monitoring requirement only.
6-7	Page 10, Table 2.5 and 2.6Is chlorine + ammonia really a CCP? How does monitoring it reduce risk?
6-8	Page 10, Table 2.5 and 2.6: Pathogens are identified as a hazard. So, perhaps biologically active filtration (BAF) is a potential CCP that could be expected to reduce pathogen concentrations as a hazard. If a monitoring parameter can be identified that is indicative of pathogen reduction, it could be used for this purpose as a CCP parameter. Perhaps a parameter such as turbidity would be predictive of pathogen reduction performance by this process. Looking for such a predictive indicator for CCP monitoring would be advisable to see if it could be used to monitor pathogen reduction performance.
6-9	Page 10, Tables 2.5/2.6: The proposed free chlorine CT may be too low to consistently achieve 4-log virus reduction. Some human enteric viruses are likely to have a CT greater than either 4.8 or 15 mg-min/L. Consider specifying a higher free chlorine CT as a CCP.
6-10	Page 13, Table 2.7. Flocculation-sedimentation may be a good candidate for operational control based on turbidity reduction through coagulant dose optimization and other process control parameters. HRSD may wish to consider the potential to control flocculation-sedimentation for pathogen reduction as a hazard control treatment process.
6-11	Page 17, Table 2.8. BAF is given no credit for pathogen removal here, but elsewhere it is allocated a pathogen LRV of 0 to 3 logs. It would be advisable to determine if pathogen LRVs for this process are possible based on process LRV data from previous and current studies.
Document 7. Attachment H: SWIFT Advanced Water Treatment Pilot Data Review	
7-1	While this document presents copious amounts of data, the analytical procedures are not documented, the objectives of the analyses are seldom presented, and the results are neither discussed nor interpreted. Apparently, the final pilot plant report is not complete, so this document is the best available. Although the document may be sufficient to meet the requests of the agencies reviewing the UIC submission, the document would be more useful to the reviewers if it included an introduction, summary discussion, and conclusions. The Panel recommends HRSD create a succinct cover document to explain HRSD’s reasons for designing the pilot, along with conclusions.

7-2	Slide 23: Were microbial reductions determined for coagulation-flocculation studies? If so, why are they not reported here?
7-3	Slide 26: Was pathogen reduction data obtained for ozone? I f so, why was it not reported here?
7-4	Slide 70: Data presentation is unclear here. What do the 50 percent and 99 percent values represent? Electroconductivity (EC) is reduced extensively to 0 values (non-detects) at the 50th percentile and is reduced to 0 values at the 99th percentile, except for values of 1 for S2 and S4.1. Total coliform (TC) values are not easy to interpret because TCs can regrow or come from extraneous sources.
7-5	Slide 71: It was indicated that 96 CECs were measured at each location for all sampling dates. However, the list of these CECs was not included. It is important to identify the 96 targeted CECs, indicate the method detection limit (MDL) for each CEC, and report the concentrations detected on each sampling date. It is not clear if all compounds in Contaminant Candidate List 4 (CCL4) were included in the 96 target CECs measured. EPA announced the Final CCL 4 on Nov 17, 2016, which is a list of contaminants not currently subject to any proposed or promulgated national primary drinking water regulations, but are known or anticipated to occur in public water systems.
7-6	Slide 70: The data presentation is unclear. What do the 50-percent and 99-percent values represent? The EC is reduced extensively to 0 values (non-detects) at 50th percentile to 0 values at the 99th percentile, except for values of 1 for S2 and S4.1. TC values are not easy to interpret because they regrow or come from extraneous sources.
7-7	Slide 71: For S6 (left column, UVD effluent), 5 of 57 samples are TC positive and only 2 of 55 samples are EC positive. For S10 (UVAOP), 4 of 47 are TC positive and 0 of 47 are EC positive. For enterococci, 0 of 4 are positive for S6 (UVD), but 2 of 2 are positive for S10 (UVAOP). Enterococci may be a more conservative fecal indicator bacterium than *E. coli* and may be somewhat more resistant.
7-8	Slide 74: Regarding frequently measured CECs, they are measured where? All samples? Influent (to show their presence?). It is not clear what is being presented and for what purpose.
7-9	Slide 80: The 8-log reduction is notable and could be observed for MS2 from both treatment trains; however, the reported reduction for the GAC train is actually >7.5 log, not 8 log. For the RO train, the reduction is >8 log. Other reported MS2 reductions are noted, but they are not benchmarked against any proposed performance targets for the unit process indicated. It is worth considering another fecal indicator virus in addition to MS2? Viruses differ in properties that may influence their removal by treatment processes and their survival and transport in aquifers. Relying on a single virus indicator to represent the LRV responses of all enteric virus pathogens is risky.
7-10	Slide 81: The virus challenge testing data are unclear. Can it be assumed that non-detects are achieved for S6 (UVD effluent), S8 (RO effluent), and S10 (UVAOP effluent)? Such non-detects are not explicitly stated.

Acronyms: BAC = biologically active carbon. BAF = biologically active filtration. CCP = critical control point. CCL4 = Contaminant Candidate List 4. CEC = chemical of emerging concern. CL = confidence limit. CT = contact time. GAC = granular activated carbon. HAA5 = haloacetic acids. HRSD = Hampton Roads Sanitation District. IPS = influent pump station. LRV = log reduction value. MDL = method detection limit. RO = Reverse osmosis. SWIFT = Sustainable Water Initiative for Tomorrow. TC = total coliform. TOC = total organic carbon. TTHM = total trihalomethanes. UV = ultraviolet. UV AOP = ultraviolet/advanced oxidation. UVD = ultraviolet disinfected. WWTP = wastewater treatment plant

ATTACHMENT A

NATIONAL WATER RESEARCH INSTITUTE

Hampton Roads Sanitation District's
Sustainable Water Initiative for Tomorrow (SWIFT)

Independent Advisory Panel ♦ Panel Member Biographical Summaries

---

Glen T. Daigger, Ph.D., P.E., BCEE, NAE (Panel Chair)
Professor of Civil and Environmental Engineering
University of Michigan (Ann Arbor, MI)

Dr. Glen Daigger is a Professor of Engineering Practice of Civil and Environmental Engineering at the University of Michigan. As a faculty member in CEE, Daigger contributes to the teaching of practice-oriented courses and provide leadership in the pursuit of national and international research and education initiatives, while also maintaining strong ties with professional practice. Daigger, recognized worldwide as an expert in wastewater treatment technologies, has contributed significantly to the entire water industry, most recently through his work as president of the International Water Association (IWA), where he worked with water leaders around the globe to advance the science and practice of water management to create more livable cities and accelerate the rate at which people gained access to drinking water and sanitation, all while protecting the environment. Daigger has also served in senior roles for the Water Environment Federation, the American Academy of Environmental Engineers and Scientists, and the Water Environment Research Foundation. Daigger is a member of the National Academy of Engineering and received the Harrison Prescott Eddy Award from the Water Environment Federation three times. As the author or co-author of more than 100 technical papers, four books, and several technical manuals, Daigger has also contributed to advancing practice within the wastewater profession.

Daigger received his doctorate and master's degrees in environmental engineering from Purdue University, as well as his bachelor's degree in civil engineering from Purdue. In 2012, he was named a Purdue University Distinguished College of Engineering Alumnus. Daigger worked at CH2M and was the firm's first Technical Fellow, an honor which recognized the leadership that he provided for CH2M HILL and for the profession in the development and implementation of new wastewater treatment technology. His research has focused on the fundamental science and engineering supporting the advancement of technologies and practices which have been transformational for environmental engineering. These have included topics such as wastewater nutrient removal and recovery (biological and chemical), treatment process optimization and control (particularly biological treatment systems), control of activated sludge bulking and foaming, which can be debilitating and lead to excessive treatment costs if not properly addressed, and the highly efficient coupled attached and suspended growth systems.

Diana S. Aga, Ph.D.
Professor of Chemistry
University at Buffalo (Buffalo, NY)

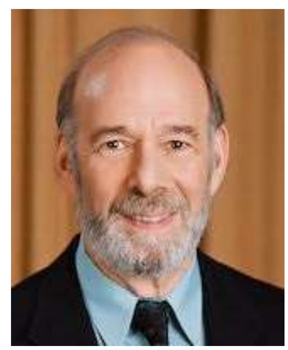
Diana Aga, a Professor in the Chemistry Department at the University of Buffalo, leads a research team that studies how various contaminants affect the environment. Her lab investigates techniques for removing antibiotics from wastewater; how plants – especially food crops – take up pharmaceuticals and engineered nanomaterials; and how levels of veterinary antibiotics in manure decrease over time through long-term storage or waste-disposal processes like composting and anaerobic digestion. Aga also has extensive experience in analyzing persistent organic pollutants, such as polybrominated flame retardants (PBDEs), and how these compounds accumulate in the human body, Great Lakes fish and the environment. Aga's insights have been published in news outlets ranging from Business First in Upstate New York to Scientific American, EcoWatch and others nationally. To investigate how chemical pollutants are transformed in the environment, and whether they pose an ecological threat, Aga capitalizes on her expertise in environmental mass spectrometry to analyze soil and water samples for traces of potentially hazardous compounds. Her research interest including industrial pollution, emerging contaminants including pharmaceuticals, nanomaterials and flame retardants, wastewater treatment, and antibiotic resistance. She received her B.S. from the University of the Philippines at Los Baños, Laguna, Philippines and her Ph.D. from the University of Kansas.

Jeffrey J. Mosher, M.S.
Chief Research Officer
Water Environment and Reuse Foundation (Alexandria, VA)

Jeff Mosher joined the Water Environment and Reuse Foundation, a nonprofit research organization located in Alexandria, Virginia, as Chief Research Officer in 2016. In this capacity, he guides WE&RF's research program, which addresses applied research in wastewater, water reuse, resource recovery, water resources, desalination, nutrient removal, resource recover, emerging water quality issues, intelligent water systems, sustainable integrated sustainable management, and energy management and production, among othe topics. Prior to joining WE&RF, Mosher served 11 years as Executive Director of the National Water Research Institute (NWRI), a nonprofit in Fountain Valley, California that works with water and wastewater agency members to develop new sources of water. Before joining NWRI, Mosher worked for the WateReuse Association and WateReuse Foundation and has provided technical, scientific, and regulatory support for U.S. EPA on drinking water regulations. His work has focused on improving water quality, evaluating advanced treatment technologies, protecting public health, and addressing regulatory issues. Mosher also has led a number of independent advisory panel efforts for water agencies, wastewater agencies, and state agencies in California, Arizona, Texas, New Mexico and other states in the U.S. to address the implementation of water supply projects, including potable reuse projects. Mosher graduated from the College of William and Mary in Virginia with a B.S. in Chemistry, and earned an M.S. in Environmental Engineering from the George Washington University.

Thomas Missimer, Ph.D., P.G.
President, Missimer Hydrological Services, Inc., and
Visiting Professor, Florida Gulf Coast University (Fort Myers, FL)

Thomas Missimer has more than 40 years of experience in the field of hydrogeology and is a recognized expert in artificial recharge and aquifer storage and recovery. He has managed more than 250 technical projects and is the author of nine books, 80 peer-reviewed articles, and 300 technical consulting reports. He is an editor of a newly released book on SWRO intakes and outfall published by Springer. He currently serves as Executive Editor of Groundwater, a technical journal for groundwater hydrogeologists. Missimer co-founded the consulting firm Missimer & Associates, Inc., and helped grow the company's revenues to exceed $25 million per year. After that, he founded another company that was purchased by CDM and was Vice President and national practice leader in artificial recharge/aquifer storage and recovery technology for CDM. He currently holds a courtesy faculty appointment at Florida Gulf Coast University. Missimer's education includes degrees in Geology from Franklin and Marshall College (BA), Florida State University (MS), and University of Miami (PhD). He is a registered Professional Geologist in the states of Florida, Georgia, and Virginia, and holds certifications from the American Institute of Professional Geologists and the National Groundwater Association. He was a past member on a science advisory panel co-convened by the California Coastal Commission and Poseidon Resources that evaluated the technical feasibility of subsurface intakes at Huntington Beach, California.



Mark D. Sobsey, PhD.
Kenan Distinguished Professor
Department of Environmental Sciences and Engineering
UNC Chapel Hill (Chapel Hill, NC)

Dr. Mark Sobsey is a Kenan Distinguished Professor of Environmental Science and Engineering in the Department of Environmental Sciences and Engineering, Gillings School of Global Public Health, University of North Carolina at Chapel Hill. Professor Sobsey is internationally known for research, teaching and service in environmental health microbiology and virology and in water, sanitation and hygiene, with more than 200 published papers and reports. His research, teaching and service encompass the detection, characterization, occurrence, environmental survival/transport/fate, treatment, human health effects characterization and risk assessment of viruses, bacteria and parasites of public health concern in water, wastewater, biosolids, soil, air, fomites and food for the prevention and control of water-, food- and excreta-borne disease. His most recent research focuses on household water treatment and safe storage for improved water quality and health and water microbiological analysis methods to distinguish between safe and unsafe water. Professor Sobsey is an author, consultant and scientific advisor to the World Health Organization, World Bank, UNICEF, US Environmental Protection Agency, US Centers for Disease Control and Prevention, the State of North Carolina and other international, national and state entities. His honors include the 2016 NWRI Clarke Prize, 2010 Water Innovation Award from the LAUNCH program, 2009 recipient of the Water Environment Federation Pioneer Award for Disinfection contributions, and 2001 recipient of the American Water Works Association A.P. Black Award for research excellence. He is a member of the International Water Association, the American Society for Tropical Medicine and Hygiene and the American Society for Microbiology. He received a B.S. in Biology and a M.S. in Hygiene from the

University of Pittsburgh, Pa. and a Ph.D. in Environmental Health Sciences from the School of Public Health, University of California at Berkeley.

R. Shane Trussell, Ph.D., P.E., BCEE
President, Trussell Technologies, Inc. (San Diego, CA)

R. Shane Trussell is the President of Trussell Technologies, Inc. Dr. Trussell has a B.S. in Chemical Engineering from the University of California (U.C.) at Riverside, a M.S. in Environmental Engineering from U.C. Los Angeles and a Ph.D. in Environmental Engineering from U.C. Berkeley. Dr. Trussell is a registered Civil Engineer in the State of California with 17 years of experience who has authored more than 57 publications and presentations. His professional experience has focused around membrane processes in the water, seawater and wastewater treatment field. He is a recognized expert on Membrane Bioreactors (MBR) and has an intimate understanding of the process limitations, both at high organic loadings and high mixed liquor suspended solids. Dr. Trussell performed his doctoral research on the effects of mixed liquor properties on membrane performance in the MBR process with Profs. Hermanowicz and Jenkins as advisors. Dr. Trussell is interested in advanced water and wastewater treatment with a focus on water reclamation and reuse. Dr. Trussell is a member of AWWA, WEF, WRF, ASCE and AIChE.

Mark A. Widdowson, Ph.D.
Professor of Civil & Environmental Engineering
Virginia Tech (Blacksburg, VA)

Dr. Widdowson is the co-author and principal investigator of the solute transport code SEAM3D (Sequential Electron Acceptor Model, 3D Transport) and the decision-support tool NAS (Natural Attenuation Software). His research expertise includes mathematical modeling and experimental studies on the fate and transport of contaminants in soil, sediments and groundwater, including chlorinated solvents (PCE, TCE, vinyl chloride); chlorinated compounds (PCBs); petroleum hydrocarbons (benzene, BTEX, MTBE), coal tar and creosote (PAH compounds); inorganics (nitrate, nitrite); metals (arsenic). His areas of research interest include: groundwater resources, fate and attenuation of contaminants in aquatic environments, modeling and decision-support tools, subsurface remediation including natural attenuation, bioremediation, phytoremediation.

A joint powers authority and 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment.

Contact: Suzanne Sharkey, Project Manager. National Water Research Institute www.nwri-usa.org
18700 Ward Street Fountain Valley, CA 92708
(714) 378-3278 or ssharkey@nwri-usa.org

Number	Comment	Initial Response
0-1	The documents in this review package were apparently produced over a period of time, some at least several months prior to this review. For example, Appendix G is dated June 7, 2017, while Appendix E was apparently produced some time ago as it presents significant actions in the future tense ("to be completed") that already have been initiated or completed per the schedule of events included in the document. Of the documents provided, only Appendix G is dated, which creates confusion from a reviewer's perspective to understand the actual current status of the information presented, what decisions have been made, and when. Each document should contain a register summarizing the sequence of issuance and review steps so that the history of development is clear. Given the evolutionary development of the material provided, a statement is needed, perhaps in the "Inventory Information Package," explaining that the information provided is current as of the date of submission of the information package.	Acknowledged. Prior to final EPA submission documents will be reviewed for common tense and up to date information.
1-1	Page 7, last paragraph in the first section, third sentence. This sentence appears to have a missing word, as "from the recharge well, until approximately 100 days." Page 7, "Piloting Advanced Treatment Processes," third sentence. Parameters do not think. The Panel suggests "considering other parameters that may become of concern in the future."	Thank you for noting these errors. They have been corrected in the text.
1-2	What evidence exists that pretreating the aquifer to only a 20-foot radius will be sufficient to control clay swelling? Because the estimated travel time is 1 week to the first monitoring well, which is located 50 feet away, it is advisable to consider increasing the pretreatment radius. Note that if clay swelling does occur, it is not reversible.	A pilot treatment event (starting 10/24/17) using 0.1 molar $AlCl_3$ conducted in a 6-inch diameter monitoring well (MW-LPA) screening the Lower Potomac Aquifer zone (LPA) successfully treated an aquifer volume extending an estimated 20 feet from the well. In a post-treatment step drawdown test, the pumping specific capacity at MW-LPA improved by 20 percent following the treatment. More important, the hydraulic characteristics of MW-LPA remained stable during a 7-day injection test conducted after the treatment. If the treatment proved a failure, the injection capacity of MW-LPA would have declined precipitously within several hours of starting the test. The volume of potable water used during the post treatment recharge test far exceeded the volume of $AlCl_3$ injected (extending beyond the 20 foot treated radius). Thus, potable water migrated outside the treated zone around MW-LPA without showing signs of clay degradation supporting a 20' treatment radius.
2-1	Page 2, Process Design Summary. The statement that "the higher TOC concentration present in the pilot effluent from the carbon train does not equate to a higher human health risk," which is based only on the lack of endocrine or cytotoxic response in the respective bioassays, is not strictly true. Total organic carbon (TOC) is a precursor to disinfection byproducts, which are not measured by the bioassays. The higher the TOC, the higher the tendency to form total trihalomethanes (TTHM) and haloacetic acids (HAA5); hence, the higher human health risk. It would certainly be possible to modify the subject statement to clarify this point, but it could lead to further confusion. The Panel suggests that HRSD remove the statement that "the higher TOC concentration present in the pilot effluent from the carbon train does not equate to a higher human health risk" and instead define the target TOC level and indicate whether the treated water met this target value.	The statement that "the higher TOC concentration present in the pilot effluent from the carbon train does not equate to a higher human health risk" is based on pilot results for EPA primary drinking water MCLs, CECs, disinfection byproduct formation, and bioassays. A slide (slide 84) has been added to the pilot results to demonstrate the disinfection byproduct formation potential of the GAC effluent with both free chlorine and monochloramine. Given that the Research Center will have approximately 6 minutes of travel time from disinfection until it is in the aquifer soil, we anticipate very low DBP formation potential in the water. Based on the extensive sampling performed as part of the pilot, HRSD proposes to leave the statement as is, with the added qualifiers listed in this response.

2-2	Page 3, Table 1: The total number of quantified emerging contaminants is listed in the table as 13 for both the Pilot Carbon train and Pilot Membrane train. It is not a correct accounting for the total detections of chemicals of emerging concern (CECs) because the table on page 71 of Attachment H lists only the number of detected CECs per sampling date without identifying them; therefore, by summing the number of detected CECs from the eight sampling dates, which most likely included several of the same types of CEC, the total number of CEC includes multiple counts of many types of CECs. In other words, if the only detected CEC during all eight sampling events was carbamezapine, the table would report eight total CECs when in fact there was only one CEC detected (i.e., carbamezapine). The tables should be corrected to identify the types of CECs detected at each sampling date and the total number of types of CECs. It is important to not count each CEC multiple times.	Comment acknowledged. The table has been updated with a new row for "Number of Unique CEC Detections". There were 13 total detections for both GAC effluent and UVAOP effluent, which consisted of 11 different CECs for GAC and 7 different for UVAOP.
2-3	Page 3, Table 1: Clarify why the Primidone concentration in the carbon train effluent is reported as a range (and it is a very narrow range: <0.005 to 0.0052 micrograms per liter (µg/L)). Is the range the detection limits? For instance, the Primidone concentration reported for the membrane train was < 0.005 µg /L, so it should be reported as non-detect. It is confusing why the detection limit in the carbon train is not the same as in membrane train. Also, it is unlikely that the analytical method is capable of distinguishing between 0.005 µg /L and 0.0052 µg /L.	Note added to the table explaining all items with a "<" were non-detect and some parameters, like primidone had a mixture of detections and non-detections.
2-4	Page 2, Table 1: It is not apparent from the data presented in the report that the 99th percentile values for total coliform and E. coli are <1 MPN/100 mL for both treatment trains because no more than 60 samples were analyzed. A larger number of analyses is needed to describe tendencies and upper-bound performance. Please explain how these values were determined.	Comment acknowledged; using the equation to calculate percentiles, a 99th percentile cannot be used with less than 100 samples. The percentile has been reduced to 95% in the table (with no change to the value) to reflect an accurate percentile calculation and to be consistent with the proposed regulatory approach (95% values will be used).
2-5	Page 6: The coagulation, flocculation, and sedimentation processes can effectively reduce pathogens in water, especially if the process is optimized for performance. Process optimization for pathogen reduction is encouraged. Efforts to associate pathogen reduction with other process performance indicators for operational monitoring, such as turbidity or particle count reduction, are potentially useful process monitoring parameters and can be encouraged for consideration. However, there is no critical control point (CCP) for coagulation-flocculation and sedimentation. The Panel would find it helpful to know the process for monitoring and validating the performance of coagulation, flocculation, and sedimentation. Consider adding a CCP validation parameter for this treatment process if a practical one can be identified.	It is acknowledged that this is an important step for pathogen removal, as shown in Table 6. Beacause the biofiltration process is providing stringent control on turbdity, we didn't think settled water turbidity (or similar) rose to the importance of critical control point but we did identify a critical operating parameter for the settled water that will functionally operate the same as a CCP. A CCP was proposed for IFE turbidity as this is the real pathogen barrier for turbidity.
2-6	Page 6, Biofiltration: It is not clear that biofiltration will achieve appreciable pathogen log reduction values (LRVs), especially for viruses, unless designed for and operated under conditions that will provide sufficient biological activity and contact time for viruses to be effectively removed and/or inactivated. Most granular media filters are poor at virus removal and inactivation without chemical pretreatment by coagulation, unless operated to promote biological activity at a slow flow rate (as in slow sand filtration). Biofiltration should be optimized and its performance better characterized for pathogen reductions if HRSD will seek LRV credits for this process. Current data for pathogen reduction has a wide range of LRVs, so a more accurate determination of LRVs based on central tendency and 95-percent confidence limit (CL) is encouraged. Efforts to associate with other performance indicators for operational monitoring is encouraged.	HRSD is seeking pathogen credits for the floc/sed and filtration process as documented on page 10 and in Table 6, per the LT2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual. This shows pathogen removal that is based on IFE turbidity requirements. It is acknowledged that additional pathogen removal is likely occurring due to the biological activity in the filters and HRSD will continue research initiatives that attempt to quantify the removal. However, this is not included in the currently proposed pathogen removal table.
2-7	Page 7, Table 2: The Panel supports the use of a "small side stream of the SWIFT Water (1 to 2 gallons per minute) will be periodically pumped to a flow-through tank, free chlorinated, and made available for consumption during tasting events held at the SWIFTRC." Is regulatory approval needed for this activity?	VDH is aware of HRSD's intent to provide this opportunity to visitors.

2-8	Page 7, Table 2: Note that the required free chlorine contact time and concentration (CT) value of 4.8 milligram-minutes per liter (mg/Lmin) may not be sufficient to achieve the target LRV of 4 for the Chlorine Concentrations x Contact Time (CT) Virus Log Removal Value (if free chlorine disinfection is practiced). Some enteric viruses, such as Coxsakievirus, may require a much larger CT value, perhaps by a factor of 5 or more, depending on temperature, pH, and other water quality conditions. Further consideration of this target CT value is advised. If chlorination will be an important barrier for this application, then choose an appropriate CT value from the literature that is protective of public health and does not compromise the tasting specifications.	A CT value of 4.8 mg-min/L was determined based on Table C-7 of the Disinfection Profiling and Benchmarking Guidance Manual to provide 4 log virus removal. The pathogen log removal shown in Table 6 is provided to show the design basis; these are non-regulatory objectives. HRSD is pursuing a risk-based approach to pathogen removal and has been measuring different virus concentrations throughout the pilot operation and at its various TPs.
2-9	Page 8 and beyond: Comment 2-9 (this comment) has ramifications throughout this documents and others. It appears HRSD has proposed an adaptive management approach to establish LRV credits for soil aquifer treatment (SAT) consisting of soil column tests (in progress at the time of the preparation of these comments) at the York River Treatment Plant, followed by other activities yet to be defined to be conducted using soil columns at the Nanesmond Demonstration Plant. It also appears that HRSD is prepared to adjust the demonstration plant advanced treatment train, if necessary, pending resolution of the credits obtainable through SAT. While the Panel is supportive of this approach, the Panel can only comment, based on the initial steps (soil column testing at York River), that the adaptive management approach appears appropriate; however, further steps are likely and have yet to be detailed and appropriately reviewed. The Panel requests that HRSD either (a) confirm the Panel has articulated HRSD's overall adaptive management approach correctly, or (b) explain HRSD's management approach if the Panel's understanding is not correct. The Panel also suggests that the approach be clearly and succinctly articulated in all relevant documents in this review package.	Comment acknowledged; the Panel's understanding of the approach regarding pathogen removal and SAT is correct. The SWIFT RC is intended to be used to better understand how to optimize the treatment process for full-scale facilities. 12 log virus removal will be achieved at full-scale through some combination of SAT (based on documented soil column and SWIFT RC aquifer monitoring), floc/sed/BAF (2 LRV), ozone (based on ability to control bromate formation), free chlorine disinfection (based on the need for this) and 186 mJ/cm2 UVD. Once SAT removal and bromate formation are better understood, the full-scale design criteria will be determined, though it may be site-specific based on different water quality.
2-10	Page 8, Paragraph 1: What is the purpose of defining LRVs in the subsurface? Will HRSD adjust the treatment train based on these definitions? If so, caution is recommended in trying to estimate virus reductions in subsurface aquifers based on modelling estimates of other parameters, as such modelling is known to be inaccurate in many cases. In situ virus monitoring may be a better predictor of virus reduction than travel time and reductions of other water quality parameters. Soil column studies also may not provide reliable information on virus reduction in aquifers, especially if done with disturbed soil materials packed into columns. Soil column studies are worthwhile if performed with the material present in the subsurface of the project site, but the data generated may not be representative of actual aquifer conditions and virus reduction performance in situ. The column test is a reasonable first step, and the Panel suggests in situ testing if an analysis of the data suggests that additional data is needed to refine the estimates. The motivation for and intended use of the soil aquifer LRV estimates should be clear, especially if it will influence the choice of the reclaimed water treatment train.	HRSD does not expect any viruses in the SWIFT water after advanced treatment and it is not practical to add pathogens (or pathogen surrogates) to the SWIFT water to quantify removal in the aquifer. Instead, HRSD intends to use the results of soil column testing and in situ virus monitoring at the Research Center to support a conservative estimate for virus removal in the aquifer that is consistent with the approach that has been taken by other states.

2-11	Page 10, Table 5: • Non-regulatory performance indicators are listed, which were chosen based on several criteria, including high occurrence in wastewater treatment plant (WWTP) effluent; however, the performance indicators should include Iohexal, based on its high frequency of occurrence and non-removal in various treatment processes. For instance, Iohexal was detected after treatment byOzone, BAC1, BAC2, GAC1, and RO, as shown in page 72 of Attachment H. • The Panel supports the concept of non-regulated performance indicators. What was the process for determining values in Table 5 for 17-β-Estradiol and ethinyl estradiol? • The rational and source of the values in Table 5 should be provided.	We acknowledge that iohexol is prevalent in the pilot testing results. The non-regulatory performance indicators (and trigger values) were selected based on the Final Report of an NWRI Independent Advisory Panel: Recommended DPR General Guidelines and Operational Requirements for New Mexico, 2016, as detailed on page 9. The purpose of the SWIFTRC is to gather additional information to allow for a tailored approach to the selection of indicators. Though we are not proposing to deviate from the NWRI DPR framework at this time, it is important to note that iohexol monitoring will continue at the SWIFTRC at the same frequency as the indicator parameters. Missing from the table of monitored parameters is the more extensive list of emerging contaminants, including iohexol, that will continue to be monitored to help inform the selection of appropriate indicator parameters for full-scale implementation. The more extensive list will be added to the table to give the reader a better understanding of the scope of monitoring that will be included with the SWIFTRC. These additional parameters may be modified over time to reflect occurrence data from the SWIFTRC and from the secondary effluent monitoring occurring at the other future SWIFT facilities (i.e. research focused parameters with infrequent or no observed detections will be eliminated from on-going monitoring).
2-12	Page 11, Table 6: It is advisable to narrow the range of performance for biological activated carbon (BAC). A range of zero to three (0-3) log removal is too variable and uncertain. An effort should be made to better specify the expected LRV based on actual performance data from lab- and pilot-scale studies to determine average and range of LRVs as 95%-percent CLs. The Panel recognizes that HRSD will be gathering data to respond to this comment.	Note that the 0-3 range was provided for ozone, not BAC. 3 log removal for virus through the ozone process will be targeted and the Research Center will be operated to meet this set point, depending on bromate mitigation success. However, based on SAT virus removal, HRSD is suggesting that the ozone dose may be reduced in the future.
2-13	Page 11, Table 6: It is advisable to obtain better data on the extent of virus removal by ozone because a 0-3 log reduction range has high variability and uncertainty that can be reduced. This variability may be reduced to develop a more precise estimate of ozone LRV, with mean and median values and 95-percent CLs. Further studies are recommended to address this matter. The Panel recognizes that HRSD will gather data to respond to this comment.	HRSD intends to operate the Research Center to achieve 3 log virus removal, as calculated using the Long Term 2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual. If this level of ozone dose produces excessive bromate, the ozone dose may be reduced such that no virus credit is granted. This is why a range of values is shown in the text. If 3 log virus credit cannot be achieved through ozonation due to bromate control concerns, free chlorination will be employed to provide needed virus LRV until virus removal by SAT can be confirmed.
2-14	Page 11, UV dose: Will the UV reactor be validated on site?	No, the reactor was factory validated by the equipment vendor at a dose of 186 mJ/cm2. HRSD has reviewed the confidential third party validation report and is satisfied with the validated performance.
2-15	The lack of LRV credit for viruses, Cryptosporidium, and Giardia by BAC-GAC is questionable and needs further documentation. BAC may be able to reduce viruses and protozoan parasites to some extent, depending on operating conditions, because other biological processes can reduce enteric viruses and protozoan parasites; therefore, under some design/operating conditions, BAC may achieve measurable LRV reductions. Are BAC LRVs being sought? If such LRV are refined based on new data, how will these data be used in managing this treatment process?	Pathogen removal for biofiltration, as part of the conventional treatment process, is shown in Tables 6 and 7. These LRV credit for the combination of coagulation, flocculation, sedimedation, and granular media filtration are specifically called out in the first column of Tables 6 and 7 "Floc/Sed + (BAC)". HRSD has collected data demonstrating that there is pathogen removal through the BAC-GAC processes. However, the intent of Tables 6 and 7 is to document credit based on design criteria as acknowledged by EPA, not based on data. HRSD will continue to collect pathogen removal data at the Research Center, pilot, and existing treatment plants, to further advance the understanding of pathogen risk and removal.
2-16	Page 12: To receive credit for TOC reduction through SAT and to modify the TOC regulatory limit at the wellhead accordingly, HRSD will need to: 1) conduct a modelling study each well or well field to confirm travel times; and have monitoring requirements at monitoring wells to verify the water quality.	Acknowledged.

2-17	Page 12, Table 7: For tasting events, how will HRSD ensure LRVs of at least 10 for protozoa? The predicted range is 8 to 12.	The range "8-10" was shown because only 4 LRV credits are currently recognized by states for a UV dose of 186 mJ/cm2. However it is widely accepted in the treatment community that greater than 6 log removal of protozoa is achieved at this dose. Therefore, 6 LRV is proposed in the document (for a total of 10 in the process train) though it is acknowledged that states currently would only count 4 (for a total of 8). HRSD also has performed secondary effluent sampling in 2016 for protozoa at NTP and all samples showed less than 10 cysts per 100 mL. The text has been edited to reflect 6 LRV as proposed.
2-18	Page 17, Table 10: What is the basis for the frequency of protozoan parasite and Legionella monitoring being only quarterly? More frequent analysis would be advisable, perhaps monthly.	These are non-regulatory parameters that have not shown in the pilot effluent throughout monthly monitoring. More extensive sampling may be performed for research purposes but only quarterly data will be submitted as part of the non-regulatory sampling.
2-19	Page 26, Table 10: It is advisable to increase the sampling frequency of coliphages from monthly to weekly. The analysis of coliphages as fecal indicator viruses is easy, fast, and economical.	See response to comment 2-18.
2-20	For CCPs, see Comment 6-1 (for Attachment G).	
3-1	For monitoring wells, the analytical schedule appears to anticipate two phenomena occurring in the aquifer, namely advection/dispersion and attenuation. But, the third phenomenon is acclimation, especially for biologically mediated transformations. The analytical protocols should anticipate acclimation, especially for biologically mediated constituents, but also potentially for others.	Acknowledged. We will continue monitoring as long as dynamic conditions continue and there is an indication that further acclimation is on-going. We will only cease sampling after conditions stabilize.
3-2	It appears that injection will occur in a single well into three zones. How will the flow be assessed for each zone? There will be a tendency for all the flow to enter the zone with the highest hydraulic conductivity.	Testing at MW-SAT will determine how the recharge flow is allocated between the Upper (UPA), Middle (MPA), and Lower Potomac Aquifers. Moreover, because of the number of discrete ports in MW-SAT, HRSD will discretize flow across the four sand intervals in the UPA, five in the MPA, and two in the LPA. We reasonably know the hydraulic conductivity of the aquifer and we believe we can estimate the flow into each zone.
3-3	On Pages 1-2, the conditioning distance states “20 to 50 feet radius,” which is different from the information in Document 1. Which distance is correct?	Based on the succes of the recent $AlCl_3$ treatment and testing conducted in the LPA, the present target conditioning distance will remain at 20 feet from the MAR well. By comparison, USGS successfully treated a test aquifer, storage, and recovery ASR well to stabilize clays using roughly 1/20 of the volume applied at MW-LPA, treating a radius less than 5 feet around the well. The petroleum industry routinely treats wells used for water flooding to a distance of 10 feet.
3-4	Page 1-4, Figure 1-2: Monitoring well MW-SAT is mislabeled.	Acknowledged. The figure will be edited prior to submitting to EPA.
3-5	As written, “well construction” is in the future tense; however, a table listing the depths and screen lengths of the 11 screens at TW-1 and corresponding data at MW-SAT is recommended. Also, the depths in Figures 1-3 and 1-4 are difficult to read.	Acknowledged. The figure will be edited prior to submitting to EPA.
3-6	Page 1-10, Section 1.3: It states that wells MW-UPA and MW-MPA contain four screens each; however, the diagrams in Figure 1-7 show two screens for MW-UPA and three screens for MW-MPA.	Acknowledged. The text was edited and the figure will be edited prior to submitting to EPA.
3-7	Page 1-10, Section 1-3: Sampling of the conventional monitoring wells using a single pump per well suggests that groundwater will be derived from multiple screens, resulting in a mixed chemical signature at each well. The use of a dedicated packer system to isolate well screens is recommended.	Hundreds of managed aquifer recharge (MAR) wells in the United States recharge, and some recover, water from wells open across several zones. Successful operation of injection type wells rarely ever requires knowing the destination of water recharged to each specific screen. From a regulatory perspective, US EPA does not require tracking recharge through every open interval in a recharge well. The testing developed by HRSD for defining flow in the Potomac Aquifer system (PAS) far exceeds efforts developed at other operational MAR sites, and most research facilities. The conventional wells will provide discritization of each of the three major aqufier zones in the PAS, this is consistent with the way production wells (the potential downstream receptors) utilize the aquifer system.

3-8	The monitoring of phosphate should be considered during operation. Biofilm formation in aquifer systems may be phosphate-limited and could occur in this injection system. Biofilms, once started, are difficult to remove and lead to aquifer clogging.	Both total phosphorus and orthophosphate are included in the monitoring plan.
3-9	Please add an explanation as to how air bubbles in the injection water will be limited, because air impaction causes rapid rates of injectivity decline.	HRSD will equip the recharge line with a downhole flow control valve that maintains a positive pressure in the line at all times. Pressurizing the recharge line will prevent entraining air bubbles into the recharge water. Furthermore, following Henry's law, bubbles collapse and dissolve in water as gauge pressure reaches 1 atmosphere. The pressure at the shallowest screen in TW-1 will exceed 12 atmospheres. Thus, a combination of hydrostatic pressures in the wellbore and the downhole flow control valve on the recharge piping will prevent the migration of bubbles into the filter pack and proximal aquifer.
3-10	Page 2-23, Section 2.3.1: Chloride is identified as a tracer when, in fact, the absence of chloride serves as a "reverse tracer." Conceptually, it means a breakthrough of recharge water will result in a reduction of chloride concentration. The opposite is shown in Figure 2-5.	Acknowledged. The figure will be edited prior to submitting to EPA.
3-11	Monitoring chloride concentration reduction as an indication of physical transport may work reasonably for MW-SAT (50-foot radial distance), but will be subject to significant uncertainty in zones where lower hydraulic conductivity increases travel time. Back-diffusion and mixing of chloride from lower-permeability materials in contact with the aquifer materials (interbedded or adjacent) is a concern. Also, at the more distant wells (e.g., MW-UPA), this approach may not produce definitive data.	Acknowledged. Solute transport modeling will be used to assess the data.
3-12	Page 2-23, Section 2.3.1: The Hach Quantab may be a reliable test for chloride ion concentrations in the field, but the accuracy is questionable. The test strips for 30 to 600 chloride Cl- are limited to increments of 10-20 parts per million.	Acknowledged. We will identify the correlation between chloride and conductivity. We have found good correlation during the soil column study and plan to develop this relationship for the SWIFTRC. We will not be using strips.
3-13	Page 2-23, Section 2.3.2: Recharge will not be even across all 11 screens based on the known heterogeneity of the aquifer. There will be considerable differences in unit injectivity. How will this be monitored? The periodic running of a dynamic flowmeter log during operation could be a means of measuring the variability of flow to the three zones.	We acknowledge there will be differences in unit injectivity, monitoring in MW-SAT will discretize the flow across the 11 screen intervals and will allow for evaluating preferential flow. The conventional wells will allow for evaluating travel time to the three major aquifer zones of the PAS. Running a dynamic flowmeter log requires halting recharge operations for at least one to two weeks to remove the pump and recharge piping, install piping for the test, conduct the logging event, removing the test piping, and then re-installing the pump and piping.
3-14	Page 2-24, Section 2.3.2: The travel time evaluation in each sand interval screened requires precise inflow measurements. How will the inflow be monitored at each open aquifer in the well?	Acknowledged. The Potomac formation represents a fluvial/deltaic enviroment resulting in many local-scale variations in lithologic character and geometric configuration - sand (and clay) intervals within the aquifer may combine or pinch out across the site. It isn't practical or necessary to track flow in each sand interval beyond much distance from the recharge well. Operators will determine travel time at MW-SAT, 50 ft away, based on the breakthrough of a tracer at MW-SAT at each screen interval.

3-15	Page 2-24, Section 2.3.3: Regarding the issue of injection rate into multi-zonal screened wells, there is always a preferential flow rate into the uppermost screened interval with a progressive downward loss of driving head. The head loss in the first screened interval causes the driving head to be lower in the next lower screened increment. In-well flow metering during injection could be used to measure the flow rates during operation. If the flow rates are not known, then all the coefficients estimated from the breakthrough curves will be incorrectly calculated.	Acknowledged. Without knowing when recharge enters a screen interval, determining accurate travel times and other hydrodynamic coefficients could prove difficult, particularly if recharge does not enter an individual screen interval upon start-up. However, the present scheme will support estimating hydraulic coefficients in screens that will obviously receive recharge at start-up, thus, yielding the most conservative travel times, an important concern to groups regulating MAR facilities and HRSD. In deeper screens that experience a delayed start, HRSD will rely on comparing the breakthrough of a tracer with the breakthrough of other constituents for estimating a semi-quantitative solution for constituent attenuation. Operational MAR wells impose a hostile environment on sensitive, downhole instruments, particularly those positioned in the screens. Frequent, bi-directional turbulent flow during backflushing events will entrain dense clouds of abrasive particulates and turbidity that will damage instruments stationed in screen intervals, reducing their accuracy or causing failure. Maintaining a network of downhole instruments protected from turbulent flow, particulates and turbidity probably requires installing a well adjacent (< 10 feet) to TW-1 with identical screen intervals.
3-16	Section 2.3.3: The method of analyzing breakthrough curves is not provided. What method(s) will be used? This comment applies for other constituents and not just tracers.	To develop the breakthrough curves, HRSD operators will sample from the eleven sampling ports in MW-SAT to intercept tracer and other important constituents as they pass the well. Concentrations of chloride, the selected tracer will decline to a stable threshold as recharge passes the well. Thus, HRSD will employ mass balance techniques to develop a breakthrough curve based on percentage of recharge water in the sample plotted against time. HRSD will employ the same approach for evaluating other constituents depending on whether concentrations are greater in the recharge or native groundwater. Depending on the empirical results, HRSD may examine several other important factors such as the adsorption capacity of aquifer materials. HRSD will also apply solute transport modeling techniques, and iteratively test coefficients of dispersivity and adsorption to best fit a solution.
3-17	Page 2-25, Section 2.3.5: The sampling interval for chloride and conductivity is given as 12 hours. This sampling interval may not produce definitive reserve breakthrough curves. Increasing the frequency is recommended.	Acknowledged. Yet, more frequent sample collection freqencies are only necessary if nearly 100 percent of the recharge enters the shallowest screen, and flow in this interval exhibits a large amount of hydrodynamic dispersion. Otherwise, a 12-hour sampling frequency should cover nearly all recharge distribution contingencies. More frequent sampling will be conducted with conductivity probe.
3-18	Page 3-1, Section 3.1.1: Injectivity loss may occur due to the process of reversing flow through the gravel pack during cleaning cycles. The loss can be corrected by redeveloping the well using compressed air and/or water surging with a packer. The screen and gravel pack design is rarely applied to a pumping well with unidirectional flow because injection wells tend to push the coarser gravel away from the screens and can cause mixing with finer material. This mixing also occurs when the wells are flushed during cleaning. The issue of bi- direction flow has not been resolved and will ultimately cause require redevelopment.	Acknowledged. Bi-directional flow (backflushing) through the screen and gravel pack intends to remove solids accumulating in this zone between backflushing events. Yet, eventually, all MAR wells require invasive rehabilitation measure to restore injectivity losses. Typically, a regime of agressive mechanical agitation through swabbing, chemical addition, and overpumping handles the siltation type clogging associated with MAR wells.
4-1	Page 2-2, Table 2-1: The Panel suggests adding “Gravel pack disruption” to the list of potential issues.	Acknowledged. The text was edited to reflect this.
4-2	Page 2-2: Note that nitrate is also an oxidizing agent that can affect mineral dissolution.	Acknowledged. The text was edited to reflect this.
4-3	Page 3-2 to 3-3, Table 3-2: Should nitrate also be included in this table?	Yes. This was added.

4-4	Section 5: Oxygen concentration in the injected water is not the only potential cause of dissolution and mobilization of various cations; rather, the overall oxidation potential of the water is significant. Arsenic mobilization has been observed in water that contains no dissolved oxygen, but has a high oxidation potential.	Acknowledged
4-5	Section 6.3.1: A description is provided of the use of monitoring well MW-LPA to test effectiveness of a hydroxy-aluminum chloride flush and develop protocols before treating test well TW-1. Given the approaching start date (April 2018), when will this analysis be completed, and how will it be incorporated into decision-making, both in the short term and in conjunction with the pilot test and in the long term?	An $AlCl_3$ treatment and injection testing was conducted in MW-LPA during October 2017 and validated the effectiveness of the treatment approach for TW-1, scheduled for early January. Despite treating only a volume equal to 20 feet around the pilot well, the treatment appeared successful in maintaining the injectivity over a 7-day test that involved a recharging a volume of potable water that exceeded the treatment zone by several times. Lessons learned on procedural set up/introducing the treatment into the well will be incorporated into treating TW-1 along with treating at more distrete packered intervals than originally planned. Long-term evaluation of the aquifer treatment process will be obtained from operation of the demonstration facility and recharge into TW-1 and will be used to guide/adjust treatment and possibly design of the full scale recharge wells.
5-1	What porosity is assumed for the soil columns? This information is important, as many calculations are based on this assumption.	The initial assumption of effective porosity was 0.35. After conducting a tracer test on all the columns and using a model to fit the effluent concentrations of the tracer , the best fit effective porosities were estimated as 0.37 and 0.34 for the 1 month columns and 0.35 and 0.38 for the 50 ft columns.
5-2	How representative is pathogen testing on the soil columns prior to establishing the biological and chemical reactions that will be present in the aquifer? What logic is this based on? Bsed on this logic, what over-estimates or under-estimates of log removals could result?	This is a good comment. Flushing of the soil columns with SWIFT pilot effluent was accomplished prior to the initiation of pathogen challenge testing, so there is some expectation of microbial growth in the soil columns during that period. Unfortunately, there was not sufficient time to allow a full acclimation of the soil columns prior pathogen challenge testing. The pathogen challenge testing was/is also being accomplished without the feed of free chlorine or monochloramine such that only removal by SAT is considered. Pathogen removal mechanisms include physical straining and sorption to sand media as well as natural die-off in the columns due to unfavorable environemental conditions. For flourescent microsheres, only physical removal is relevant. Actual Crypto oocysts would likely undergo additional die-off in the subsurface, suggesting that the soil column results would be a conservative estimate of true Crypto removal by SAT. The presence of an acclimated saprophytic biofilm in the soil columns could lead to pathogen growth or enhanced inactivation. Of course, pathogenic human viruses and protozoan cysts would not be expected to reproduce without a host, so regrowth in the aquifer is not a concern. If an appropriate MS2 host is present (coliform bacteria), MS could potentially reproduce, suggesting an interference with measurement log removal. This impact is expected to be unlikely, because effective coliform hosts should be at low concentrations in the aquifer and soil columns. The presense of biofilm and adsorbed organic material on soil grains could, however, enhance the effective removal of viruses and protozoa, suggesting that a longer term study would show increased log removal (so short-term soil column study should be conservative). An important consideration here is the enhanced die-off or enhanced physical removal (due to biofilm and organic matter accumulation) versus potential regrowth of pathogenic bacteria as a result of the establishment of a saprophytic bacterial biofilm. It is hard to predict which influence might be more important, and both mechanisms could occur (over-estimates or under-estimates for pathogenic bacteria are possible). In the end, only very conservative results will be derived from soil column testing.

5-3	Construction and initial operation of the columns have already occurred. It is confusing and misleading, as the document is not dated and presents several events that have already occurred as if they will occur in the future. The text should be adjusted to be representative of the actual sequence of events. If this document was completed in the first half of 2017, it should be indicated. Note that a review by the Panel earlier in the process would have produced more useful feedback to HRSD.	When the document was put together, the columns had not been constructed and none of the tests had started. The research is an ongoing project. Changes have been made to the document so as to address this issue.
5-4	What is the source of Potomac Aquifer System (PAS) sand used in the Phase I SAT Column testing?	The sand came out of the borehole drilled for MW-SAT.
5-5	If a clear plastic PVC pipe or glass is used, the outside of the column pipe should be painted black (fabric is not as effective in removing all light wavelengths) to avoid the growth of light-sensitive organisms within the column media, which could invalidate the results of the column study. Also, to avoid air entrapment in the column, the column should initially be flooded from the bottom upwards. One column should be run as a control without the addition of chlorine or dissolved oxygen to assess true unassisted pathogen removal (see Dehwah, A.H.A, and Missimer, T.M., 2017, Seabed gallery intakes: Investigation of the water pretreatment effectiveness of the active layer using a long-term column experiment: Water Research, v. 121, p. 95-108, Doi: 10.1016/j.water2017.05.014.) http://repository.kaust.edu.sa/kaust/handle/10754/623684	Columns were covered with thick (6 mil) black polyethylene plastic in the beginning of October. The columns were flushed with influent water for about 3 pore volumes for the 1 month columns and around 20 pore volumes for the 50 ft columns. The columns were designed and are being operated in an upflow mode, and air was removed by malleting during the initial water fill of the columns. None of the columns have/had disinfectant injected during pathogen challenge tests. The disinfectants will be injected after the sampling for pathogen tests are done. Given the input of ozone upstream of SAT, it seems unlikely that any water will be injected with low DO. Efforts were made here to enter the soil columns with the same high DO that would be present in the field.
5-6	The inflow water quality samples should be collected from the inflow pipe at the top of each column and not from a common feeder tank or reservoir. Variations in microorganism concentration commonly occur with feeder tanks.	The influent samples have been taken from the feed containers for the pathogen/ pathogen indicator tests. The feed was spiked with a known concentration of microorganisms and changed once the duration of injection. Daily pathogen/pathogen indicator samples from the feed containers were collected during the injection periods. There will be an alteration made to the sampling methodology once the columns are amended with disinfectants. The plan is to have finished water in a common feed tank. Free chlorine and monochloramine will be pumped into the influent tubing with a peristaltic pump. The flow then will split into two sets of tubing, the length of each providing 6 minutes of total detention time. One set of tubing will feed into the columns while the other set of tubing will be used to take the influent samples. This would allow for sampling without interrupting flow into the columns.
5-7	Page 3-10, Table 3-3: The Panel suggests adding orthophosphate and total phosphorus to the table.	Acknowledged. This was a mistake in the plan. We had planned to sample for orthophosphate, but not total phosphorus. TP and OP will be added.
5-8	The Panel suggests that HRSD review the column research conducted on trace contaminants by Mazahirali Alidina, Jörg Drewes, and Christaine Hopp-Jones. HRSD should take great care in the final design of the column tests because many errors have been made in the test design, which can raise scientific questions concerning the validity of the results.	Based on these papers, we did not identify any need to alter the study design. According to Alidina et al. (2014), a low peptone to humic acid ratio in the influent feed was observed to be good for the attenuation of trace organic carbons (TrOCs) through the soil columns. The influent going into the columns for this soil column experiment contains negligible amounts of readily degradable substrate. The feed water was/is treated through a treatment train that includes ozonation and biological filtration. The remaining TOC is expected to be represented by complex, recalcitrant, and slowly degradable organics that should enhance the development of a bacterial population that is effective for CEC removal.
5-9	Section 3.1, first bullet: Evaluate the removal of pathogens and pathogen indicators by SAT, with specific focus on confirming at least 1- log removal of viruses, *Cryptosporidium* , and *Giardia* per month of aquifer travel time. Note that California allows credit for 6-log removal after 6 months of travel time for *Cryptosporidium* and *Giardia* only; the 1-log removal per month value is for viruses only.	Noted.

5-10	Section 3: Are fluorescent microspheres being used in place of *Cryptosporidium* and *Giardia* ? It is not clear. If this technique is to be used, the characteristics of the microspheres must mimic those of *Cryptosporidium* and *Giardia* cysts and oocysts.	Fluorescent microbeads are being used as a surrogate for Cryptosporidium oocysts. The physical size of the microspheres is similar to the size of Cryptosporidium oocysts. Microspheres do not have a net negative charge unlike Cryptosporidium but that also means that it is a more conservative test for removal. And sufficient log removal of microbeads demonstrated would imply log removals targeted for Crypto would be met too.
5-11	Section 3: Several tables (3.3., 3.4, 3.5) are numbered incorrectly.	Acknowledged. The text was edited to reflect this.
6-1	“CCP” should be defined in the memo to underscore that it is a unit process where risk can be reduced, and that monitoring controls exist. The definition from WRRF-15-011 is “A CCP is a point in the treatment train (i.e., a unit treatment process) that is designed specifically to reduce, prevent, or eliminate a human health hazard and for which controls exist to ensure the proper performance of that process.”	This definition was added.
6-2	Page 20, Table 2.10: It is not clear if the influent pump station (IPS) can be a CCP. What is the meaningful reduction in risk provided by the IPS? The pump station should probably be a monitoring point. The Panel understands that monitoring for nitrate at the IPS is a "control." Should CCPs be allowed for the processes that do not reduce risk, but just identify the potential for risk?	IPS is a CCP because high bromide (as indicated by conductivity) and high nitrate (all TIN and a large portion of ON is converted to nitrate) are protective of bromate and nitrate, which are primary MCLs and health concerns.
6-3	Table 2.9: Please explain the process for monitoring for ozone CCPs.	As indicated in Table 2-10, failure of the ozone system as indicated by an alarm from the ozone generation/feed/injection/destruct control systems will result in a CCP. In addition, ozone CT and virus LRV will be controlled and measured online. Virus LRV is a CCP.
6-4	Table 2.9: For GAC, how will performance be assessed just by monitoring the effluent TOC?	Online GAC effluent TOC monitoring will assess the GAC performance with regards to TOC removal. SWIFT water TOC is a regulatory requirement.
6-5	Table 2.10: Conductivity is listed as a parameter for the IPS. How does conductivity at the IPS control for nitrate, nitrite, pathogens, and DBP precursors?	Conductivity is included because it is a surrogate for bromide. High bromide can lead to excessive bromate formation which is a human health concern.

6-6	Table 2.10: It is not clear that conductivity, turbidity, and nitrogen testing at the IPS constitutes a CCP. Although these parameters should be monitored and alarms should exist, the CCPs should be something very specific to risk reduction. The monitoring proposed for these parameters seems like an operational monitoring requirement only.	Each of these presents protection to human health. See reponse to comments 6-2 and 6-5 for conductivity and nitrogen. Turbidity is included because this represents a major upset in the WWTP process which could present human health concerns.
6-7	Page 10, Table 2.5 and 2.6Is chlorine + ammonia really a CCP? How does monitoring it reduce risk?	Preformed monochloramine is required for bromate suppression. Absence of chemical addition could lead to bromate values in excess of the MCL.
6-8	Page 10, Table 2.5 and 2.6: Pathogens are identified as a hazard. So, perhaps biologically active filtration (BAF) is a potential CCP that could be expected to reduce pathogen concentrations as a hazard. If a monitoring parameter can be identified that is indicative of pathogen reduction, it could be used for this purpose as a CCP parameter. Perhaps a parameter such as turbidity would be predictive of pathogen reduction performance by this process. Looking for such a predictive indicator for CCP monitoring would be advisable to see if it could be used to monitor pathogen reduction performance.	Biofilter individual filter effluent (IFE) turbidity and combined filter effluent (CFE) turbidity are both CCPs for this purpose.
6-9	Page 10, Tables 2.5/2.6: The proposed free chlorine CT may be too low to consistently achieve 4-log virus reduction. Some human enteric viruses are likely to have a CT greater than either 4.8 or 15 mg-min/L. Consider specifying a higher free chlorine CT as a CCP.	See response to comment 2-8.
6-10	Page 13, Table 2.7. Flocculation-sedimentation may be a good candidate for operational control based on turbidity reduction through coagulant dose optimization and other process control parameters. HRSD may wish to consider the potential to control flocculation- sedimentation for pathogen reduction as a hazard control treatment process.	See response to comment 2-5.
6-11	Page 17, Table 2.8. BAF is given no credit for pathogen removal here, but elsewhere it is allocated a pathogen LRV of 0 to 3 logs. It would be advisable to determine if pathogen LRVs for this process are possible based on process LRV data from previous and current studies.	See response to comment 2-12; the 0-3 LRV credits are for ozone, not BAF.
7-1	While this document presents copious amounts of data, the analytical procedures are not documented, the objectives of the analyses are seldom presented, and the results are neither discussed nor interpreted. Apparently, the final pilot plant report is not complete, so this document is the best available. Although the document may be sufficient to meet the requests of the agencies reviewing the UIC submission, the document would be more useful to the reviewers if it included an introduction, summary discussion, and conclusions. The Panel recommends HRSD create a succinct cover document to explain HRSD's reasons for designing the pilot, along with conclusions.	HRSD intends to write a short form pilot report for this purpose. Though the report will not be completed in time for submitting for UIC authorization, HRSD will work to have this completed prior to the end of February 2018.
7-2	Slide 23: Were microbial reductions determined for coagulation-flocculation studies? If so, why are they not reported here?	Slide 69 shows average reduction in Total Coliform and E. Coli data through the floc/sed process. Slide 80 shows the MS2 log removal demonstrated through the floc/sed process.
7-3	Slide 26: Was pathogen reduction data obtained for ozone? I f so, why was it not reported here?	Slide 80 shows MS2 reduction across ozone during virus challenge testing.
7-4	Slide 70: Data presentation is unclear here. What do the 50 percent and 99 percent values represent? Electroconductivity (EC) is reduced extensively to 0 values (non-detects) at the 50th percentile and is reduced to 0 values at the 99th percentile, except for values of 1 for S2 and S4.1. Total coliform (TC) values are not easy to interpret because TCs can regrow or come from extraneous sources.	The "EC" data set is for E. Coli, not electrical conductivity. E. Coli was reduced extensively while the Total Coliform data shows the propensity for regrowth within the process train. Though the S6 and S10 data for Total Coliform demonstrate extensive reduction.
7-5	Slide 71: It was indicated that 96 CECs were measured at each location for all sampling dates. However, the list of these CECs was not included. It is important to identify the 96 targeted CECs, indicate the method detection limit (MDL) for each CEC, and report the concentrations detected on each sampling date. It is not clear if all compounds in Contaminant Candidate List 4 (CCL4) were included in the 96 target CECs measured. EPA announced the Final CCL 4 on Nov 17, 2016, which is a list of contaminants not currently subject to any proposed or promulgated national primary drinking water regulations, but are known or anticipated to occur in public water systems.	The reference to 96 CECs is the suite of trace organics that Eurofins performs as part of its PPCP testing. Additional sampling was performed to target the majority of the CCL3, CCL4, and UCMR data sets, though this was for research purposes only and was not used as input for the proposed regulatory criteria. The pilot report will include this data and the MDL.

7-6	Slide 70: The data presentation is unclear. What do the 50-percent and 99-percent values represent? The EC is reduced extensively to 0 values (non-detects) at 50th percentile to 0 values at the 99th percentile, except for values of 1 for S2 and S4.1. TC values are not easy to interpret because they regrow or come from extraneous sources.	See response to comment 7-4.
7-7	Slide 71: For S6 (left column, UVD effluent), 5 of 57 samples are TC positive and only 2 of 55 samples are EC positive. For S10 (UVAOP), 4 of 47 are TC positive and 0 of 47 are EC positive. For enterococci, 0 of 4 are positive for S6 (UVD), but 2 of 2 are positive for S10 (UVAOP). Enterococci may be a more conservative fecal indicator bacterium than *E. coli* and may be somewhat more resistant.	0 of 2 Enterococcus data points are positive for S10 (UVAOP).
7-8	Slide 74: Regarding frequently measured CECs, they are measured where? All samples? Influent (to show their presence?). It is not clear what is being presented and for what purpose.	Pilot influent, GAC effluent, and UVAOP effluent were sampled monthly for CECs. The intermediate processes (ozone effluent, BAC effluent, RO effluent) were sampled once every 2 months.
7-9	Slide 80: The 8-log reduction is notable and could be observed for MS2 from both treatment trains; however, the reported reduction for the GAC train is actually >7.5 log, not 8 log. For the RO train, the reduction is >8 log. Other reported MS2 reductions are noted, but they are not benchmarked against any proposed performance targets for the unit process indicated. It is worth considering another fecal indicator virus in addition to MS2? Viruses differ in properties that may influence their removal by treatment processes and their survival and transport in aquifers. Relying on a single virus indicator to represent the LRV responses of all enteric virus pathogens is risky.	During the virus challenge test, there was no virus detected in the GAC effluent or the RO effluent so it is difficult to quantify the actual removal through those processes and subsequent process. Thus, ">" was used. HRSD intends to perform follow up virus challenge testing where the MS2 is spiked directly in front of the GAC process. HRSD is also considering using different viruses or surrogates for future challenge testing.
7-10	Slide 81: The virus challenge testing data are unclear. Can it be assumed that non-detects are achieved for S6 (UVD effluent), S8 (RO effluent), and S10 (UVAOP effluent)? Such non-detects are not explicitly stated.	Correct, see comment 7-9.

VirginiaTech
College of Engineering

The Charles Edward Via, Jr. Department of Civil and Environmental Engineering
Amy Pruden, Ph.D.
418 Durham Hall
Blacksburg, Virginia 24061-0246
Phone: (540) 231 3980 Fax: (540) 231 7916
E-mail: apruden@vt.edu

11 December 2017

Ted Henifin,
P.E. General Manager
Hampton Roads Sanitation District

RE: Review of SWIFT

Dear Dr. Henifin:

I am pleased to provide assistance in external review of the plans and progress for the SWIFT Research Center.

Overall, I find the progress to date and plan moving forward to be comprehensive and well-grounded in the current state-of-the knowledge for production of high quality water for potable reuse, including ozonation, carbon-based treatment, UV disinfection, chlorination/chloramination, soil aquifer treatment, managed aquifer recharge, and substantial residence time in the aquifer before reaching monitoring wells (100d to 1 yr) and consumers (several years). The approach brings in the necessary expertise from water treatment to managed aquifer recharge, hydrologic modeling, geochemistry, and hazard analysis. The aim is to route the tertiary treated water to the Potomac aquifer and match the local geochemistry of the aquifer. Overall, it's critical to bear in mind the consequences of NOT proceeding with a plan for managed aquifer recharge, as detailed here. Specifically, the subsidence of the aquifer is a major concern, along with the need to reduce nutrient loads to the sensitive ecosystem of Chesapeake Bay and to ensure water supply for Virginia's future.

I am highly supportive of the research and management direction, as laid out in memos B, C, D, E, and G, and only have a few minor suggestions. In particular, the SWIFT Research Center at Nansemond will provide invaluable guidance and training grounds as SWIFT eventually moves forward to encompass up to seven wastewater treatment facilities in the region. Currently there are no federal requirements, only guidelines, for water reuse. Thus, the initiative has drawn heavily from the knowledge-base of NWRI and experience in California, benchmarking water quality targets to potable water standards and those achieved for other successful water reuse facilities. Overall, the removal of contaminants of emerging concern (CEC) by the carbon-based system at the SWIFT Pilot at York River is highly impressive and comparable with that of RO. My main comment would be that as the research and application progresses, that there is a plan in place to consider new CECs that may be added to the list, such as antibiotic resistance genes (ARGs) currently being considered by the State of California expert panel on emerging contaminants. In my mind, the more proactive the better and it is the biological contaminants that present the greatest unknowns. The team has been wise to carry out challenge studies of virus and cryptosporidium and should continue to do so. Also, it should be factored in that there could be federal regulations at some point in the future.

Thus far, removal of pathogens seems encouraging, and with the added benefit of soil-aquifer-treatment and extended residence time in the aquifer, is not anticipated to be a problem. There are plans to begin chlorine or chloramines-based disinfection of the treated water before re-charging the aquifer. I don't believe that I have seen these data, but just a note that testing and optimizing the dosing will be important. The SWIFT water will likely have higher chlorine demand than an RO water, and there is greater potential in my mind for disinfection by product formation, which should be watched closely.

The soil-aquifer treatment study seems to be progressing well. I did not see any plans to monitor pathogens at the monitoring wells. I would not expect to see any, since the SWIFT water will be closely monitored and managed to ensure it is below detection for several bacterial, viral, and protozoan pathogen and indicator targets. However, I think it would be useful to have some sort of microbial community analysis to understand what is actually in the wells as a baseline before injecting the aquifer and as the well well heads begin to be influenced by the SWIFT water. Aside from any potential pathogen markers, it could prove useful to understand on native bacteria in the aquifer are responding to the new water and if there are any concerns in terms of biogeochemical shifts. Bacteria can be very useful indicators for biological processes occurring.

I also am generally supportive of the HACCP framework for understanding, monitoring, and managing multiple control points/barriers for the plans to inject SWIFT water to groundwater. Using the Occoquan Watershed Monitoring Laboratory as a model and applying lessons learned makes sense.

In sum, this is an impressive, important, and scientifically-grounded initiative and I look forward to monitoring progress as SWIFT progresses into the future.

Sincerely,

Amy Pruden

Amy Pruden, PhD
W. Thomas Rice Professor

HRSD

January 22, 2018

Transmitted via email: apruden@vt.edu

Amy Pruden, PhD
The Charles E. Via, Jr. Department of Civil and Environmental Engineering
Virginia Tech

Dear Dr. ~~Pruden~~: Amy

Thank you for investing your time and expertise in the review of the technical documents supporting HRSD's submission for authorization to operate its recharge well at the SWIFT Research Center. As you know, we are very interested in better understanding soil aquifer treatment (SAT) as it relates to SWIFT. The SWIFT Research Center (SWIFTRC) will be configured with a network of monitoring wells that will be used to assess the impact of recharge water on aquifer water quality, the potential benefits of SAT, and the migration of recharge water through the Potomac aquifer system.

One of your comments on the SWIFTRC monitoring plan was to include microbial community and antibiotic resistance gene (ARG) analysis in this monitoring plan. We completely agree with this recommendation. We would like to perform microbial community analysis (with focus on both pathogenic and saprophytic organisms) and emerging concerns like ARG analysis on both samples from the fully treated SWIFT water as well as samples from the network of monitoring wells. We will coordinate with you on a sample plan for baseline and post-recharge sampling of the aquifer.

We appreciate your support of the SWIFT program and look forward to continued partnering in research to better understand and protect the health of the aquifer system.

Sincerely,

Ted

Ted Henifin, P.E.
General Manager

Mitchell, Jamie

From:	Mark W Luckenbach <luck@vims.edu>
Sent:	Friday, December 08, 2017 4:02 PM
To:	Mitchell, Jamie
Cc:	Bott, Charles; Dano, John; Henifin, Ted; Lyle M Varnell; Emily A. Hein
Subject:	Re: Invitation for SWIFT program review: follow-up

Jamie et al.,

I, with the help of colleagues at VIMS, have gone through all of the SWIFT program materials that you sent. My comments will be brief, so I have chosen to put them in the form of an email rather than a letter format. First, I would like to thank you for including us in the list of reviewers. Having said that, I will note that most of the technical aspects of the project lie outside our areas of expertise at VIMS. We do not have any engineers or groundwater hydrologists on staff, so we are unable to comment on most technical aspects of the project.

We are impressed by the monitoring program framework that you have proposed and commend you for your commitment to having an independent oversight committee and a university-based monitoring program. While we again are not fully qualified to evaluate your water quality and aquifer monitoring, geochemical evaluation, soil aquifer treatment and HACCP monitoring plans, they do appear to provide a good foundation that can be further refined as needed in partnership with the the independent Monitoring Program. You have identified a robust suite of water quality parameters to measure in both the SWIFT effluent and the Potomac Aquifer System, but the concern remains that we don't know what we don't know to monitor, and we cannot monitor everything. Given the seemingly endless possibilities for current and emerging chemicals, pharmaceuticals and microbes to cause concern in the future, we would recommend that, as part of developing the details of sampling plans, you develop plans to collect, properly preserve and archive samples of the SWIFT effluent and the PAS, for future use in retrospective studies should the need arise.

VIMS does have technical expertise that it can bring to the monitoring laboratory in the areas of analytical chemistry and microbial genetics, as needed.

Please let me, if we can provide you with any additional information.

Regards

Mark W. Luckenbach
Associate Dean of Research and Advisory Services
Professor, School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
P.O.Box 1346
Gloucester Point, VA 23062-1346
804-684-7108
luck@vims.edu

From: "Mitchell, Jamie" <JMITCHELL@HRSD.COM>
Date: Monday, December 4, 2017 at 3:16 PM
Cc: Charles Bott <cbott@hrsd.com>, "Dano, John" <JDano@hrsd.com>, "Henifin, Ted" <EHenifin@hrsd.com>
Subject: Invitation for SWIFT program review: follow-up

HRSD

January 22, 2018

Transmitted via email: luck@vims.edu

Mark Luckenbach, PhD
Department of Biology
William and Mary
Virginia Institute of Marine Science

Dear Dr. Luckenbach:

Thank you for investing your time and expertise in the review of the technical documents supporting HRSD's submission for authorization to operate its recharge well at the SWIFT Research Center (SWIFTRC). We appreciate your recommendations regarding the need to archive samples for potential retrospective analyses. Archiving of samples is something that our team has considered. We have already archived some samples for organic and emerging contaminant analysis associated with the pilot-scale advanced treatment testing at the York River Treatment Plant.

Archiving samples without specific analytes in mind is particularly challenging as sample preservation and analytical preparation vary so widely. For this reason, we are planning to preserve whole water samples at -18C for potential use in retrospective analyses. Baseline groundwater samples from the SWIFTRC monitoring well network will be archived. After managed aquifer recharge begins, additional groundwater samples will be collected from the monitoring wells once the injection front has moved through and stabilized. SWIFT water samples, representing the final effluent from the advanced treatment train at the SWIFTRC, collected at the injection wellhead will also be archived.

We appreciate your support of the SWIFT program and look forward to continued partnering in research to better understand and protect the health of the aquifer system.

Sincerely,

Ted Henifin, P.E.
General Manager

G. Schafran Comments on Attachment B - SWIFT UIC Inventory Information Package

Comment/Question	Page	Section	Paragraph	Table	Figure	Response to Comments
Attachment needs an acronym definition sxn. Look at Attachment G.	1		Noted at the top of the page			We will add this into each of the documents.
Numbering of sections would be helpful when referencing from one sxn to information in another	1		Noted at the bottom of the page			We will add this when the documents are reformatted.
VDH Approval required?	2	SWIFT Research – General Purpose	3			VDH is aware of our intention to provide this opportunity.
A pre-treated sample also analyzed?	2	Process Design Summary	1			Samples were collected of secondary effluent and after each unit process (i.e., post ozone, post-BAC, etc).
< value indicate reporting limit/deflection limit?	3	Process Design Summary	Noted at the top of page – referring to table	1		Yes, a footnote was added to clarify this.
The train selected had the lower # of samples – separated in time?	3	Process Design Summary	Noted at the bottom of the page after table			The train selected (carbon) had more sample points for all of the emerging contaminants except for NDMA. Given the continued runtime of the membrane units and our 2017 focus on NDMA removal, many more NDMA samples have been collected on the carbon train.
Particle size analyzer (or turbidimeter on final effluent?	5	Process Design Summary	Noted at the bottom of the page after Figure		1	SWIFT Water and GAC Contactor effluent will both have turbidity measurements.
This diagram doesn't show it and nowhere is it explicitly stated that biofilters are being run parallel. Are there four run this way or 3 and a standby?	5	Process Design Summary	Noted at the bottom of the page after Figure		1	There are 4 biofilters that will be operated in parallel. When one biofilter is out of service or in backwash, 3 biofilters will be operated in parallel.
Final effluent or biofiltration effluent?	6	Process Design Summary	3rd bullet			Biofiltration effluent
Standard regeneration by removal and combusting in high-T furnace?	6	Process Design Summary	4th bullet			Yes
Separate transfer and contact reactors?	7	Process Design Summary	Ozone Contactor Hydraulic Residence Time	2		See design documents, sidestream O3 injection system + pipeline contactor. This residence time is for the pipeline contactor only.
In series?	7	Process Design Summary	Number of GAC Reactors and GASC Vessel Empty Bed Contact Time, combined two vessels	2		GAC vessels can be operated in parallel or in series lead-lag.
Required by whom? What LRV is this?	7	Process Design Summary	Last three rows of table	2		See Table 6, up to 4 LRV virus
Who is regulating under what permit?	8	Compliance Point Locations	1			EPA UIC (region 3)
?	8	Compliance Point Locations	1 mid-sentence – "MW-SAT"			MW-Sat is the monitoring well located 50 feet from the injection well. See Attachment C.
Targets as opposed to required limits?	8	Compliance Point Locations	2			The targets proposed here are likely to emerge as firm limits with the full-scale SWIFT permit. The purpose of these documents is to define targets for the Research Center. Data from the operation of the Research Center will inform a full permitting process that is intended for the full-scale build out.
Makes it sound as if there are no regul. limits just "targets" established by HRSD.	8	Compliance Point Locations	2			There is little precedent for this in Virginia. This regulatory approach has been and will continue to be reviewed by numerous stakeholders – VADEQ, VDH, EPA, NWRI independent panel, VA members of academia, etc.
They are a measure of the level of trt. achieved.	8	SWIFT Water Quality Targets for SWIFTRC	1 – last sentence			Acknowledged

G. Schafran Comments on Attachment B - SWIFT UIC Inventory Information Package

Comment/Question	Page	Section	Paragraph	Table	Figure	Response to Comments
Odd Statement	8	SWIFT Water Quality Targets for SWIFTRC	1 – 2nd to last sentence			This approach is consistent with other indirect potable reuse projects.
Where is a discussion of the regulatory env. And regulations that this program would operate under?	8	SWIFT Water Quality Targets for SWIFTRC	Noted at the bottom of the page			See UIC inventory document
EPA GW injection req's?	9	SWIFTRC Regulatory Limits	1			Table 4 documents the regulatory limits as negotiated with VDH. As a demonstration-scale injection facility, the SWIFTRC will not be individually permitted but will be authorized by rule. EPA does not have a set of pre-determined limits for Class V injection wells but does require the protection of the underground sources of drinking water.
Are these to be negotiated with EPA?	9	SWIFTRC Regulatory Limits	Noted on the side of paragraph 1			The targets proposed here were negotiated with VDH and are likely to emerge as firm limits with the full-scale SWIFT permit. The purpose of these documents is to define targets for the Research Center. Data from the operation of the Research Center will inform a full permitting process that is intended for the full-scale build out.
Define what Proposed RL is.	9	SWIFTRC Regulatory Limits	Proposed Regulatory Limit Column	4		The targets proposed here were negotiated with VDH and are likely to emerge as firm limits with the full-scale SWIFT permit. The purpose of these documents is to define targets for the Research Center. Data from the operation of the Research Center will inform a full permitting process that is intended for the full-scale build out.
I feel this column is misnamed and not Water Quality Goal.	9	SWIFTRC Regulatory Limits	Water Quality Goal Column	4		Acknowledged. Text was modified to "Non-regulatory action/goal".
This could be interpreted as 20 samples/day as written	9	SWIFTRC Regulatory Limits	Total Coliform row, Proposed Regulatory Limit column	4		Acknowledged. Text was modified.
What is the "goal" here?	9	SWIFTRC Regulatory Limits	Turbidity and Total Organic Carbon rows, Water Quality Goal column	4		See Table 8 for further information.
Why is this not applicable?	9	SWIFTRC Regulatory Limits	Total Coliform and E. Coli rows, Water Quality Goal column	4		There is no goal, only a limit.
Is this the same as the sxn titled "regulatory sampling plan"	9	SWIFTRC Regulatory Limits	Footnote 1 – SWIFTRC Sampling Plan	4		Edited text to point readers to Table 10.
This statement suggests an online analyzer is also part of the monitoring	9	SWIFTRC Regulatory Limits	Footnote 2	4		A six-channel TOC analyzer is part of the SWIFTRC. See P&ID.
If these are performance indicators then typically they are used to provide rapid feedback and allow correction/adjustment. If these values are averaged over a large # of sample a high value could be "averaged" to below the PI value.	9	Performance Indicators	Noted at the bottom of the page			The turn-around time for these analytes is up to 1 month. These are not intended for rapid feedback.
Based on this statement and others that indicate turb. Will also be monitored in real time, why aren't these locations showing in fig.1?	9	Performance Indicators	1 – 2nd sentence			Fig 1 is intended to be a simplified PFD. All instruments are shown best in the P&ID in the detailed drawings package.
Which one Identify by CCL#?	9	Performance Indicators	1 – sentence beginning "Table 5 provides			Edited text. See Tables 5 and 10.

G. Schafran Comments on Attachment B - SWIFT UIC Inventory Information Package

Comment/Question	Page	Section	Paragraph	Table	Figure	Response to Comments
			information" mid-sentence after "EPA"			
What period of time sampling and calculating the average?	9	Performance Indicators	1 – sentence beginning "If the running average"			Quarterly sampling frequency. Time period for running average will be determined based on variability of data.
Volume 3 of what?	11	PAS Recharge	Ozone - 1st bullet			Error. Corrected text. This should be Attachment E.
By whom?	11	PAS Recharge	2nd bullet – 2nd to last sentence "accepted/acknowledged"			The water treatment industry.
THM & HAAs? > MCL?	11	PAS Recharge	3rd bullet			TTHM and HAA5 will be monitored regardless of free chlorination or combined chlorination per Table 10.
How would you evaluate SAT removal?	11	PAS Recharge	4TH bullet			See Attachment E for discussion of soil column testing. Also monitoring in MW-SAT and other monitoring wells provides an indication of formation of DBPs and subsequent degradation through SAT.
The first mention of this action/evaluation. Is there another tech memo that can be referenced here?	11	PAS Recharge	4th bullet – last sentence			See attachment E. Text was adjusted.
This sentence can be deleted as it is only confusing.	12	Tasting	1st paragraph – last sentence			Deleted.
Is this term (and acronym) to differentiate from abnormal unmanaged aquifer recharge?	12	Tasting	2nd bullet "normal managed aquifer recharge (MAR)			Text adjusted to normal recharge operations.
Warranted	12	Tasting	3d bullet- 'assumed"			Text adjusted.
Reduced	12	Full-Scale SWIFT Facility Considerations	1st paragraph – 3rd sentence "relaxed"			Text adjusted.
Incomplete sentence	12	Full-Scale SWIFT Facility Considerations	1st paragraph – second to last sentence, "If significant reduction of organics is demonstrated by soil column testing"			Text adjusted.
These are not the terms used in Table 8. I think also they have been reversed (what is called action is actually alarm level and alarm is alert)	13	Full-Scale SWIFT Facility Considerations	2nd paragraph (1st full paragraph) use of alarm, and action			Text adjusted.
What is HACCP?	13	Full-Scale SWIFT Facility Considerations		8		See Attachment G.
Alarm Value	13	Full-Scale SWIFT Facility Considerations	Action column	8		Text adjusted.
Total inorganic nitrogen?	13	Full-Scale SWIFT Facility Considerations	Influent Pump Station TIN row	8		Text adjusted.
Is there really an action, e.g. incr. freq. of monitoring, that is triggered? If there is truly no action they should be deleted.	14	Full-Scale SWIFT Facility Considerations	Action Column	8		There need not be a defined action for a COP. These parameters were deemed sufficiently important to warrant attention by the operator.
≥	14	Full-Scale SWIFT Facility Considerations	Alert Value Column: added before value in Influent Pump Station	8		Inferred.

G. Schafran Comments on Attachment B - SWIFT UIC Inventory Information Package

Comment/Question	Page	Section	Paragraph	Table	Figure	Response to Comments
			Nitrate, Nitrite and Ammonia			
When TIN gets to 6.0 there is an action. Is that why no alarm value here?	14	Full-Scale SWIFT Facility Considerations	Alert Value Column: added before value in Influent Pump Station Nitrate and Nitrite	8		TIN CCP is captured above.
Why list all the parameters that have "none" as the action?	14	Full-Scale SWIFT Facility Considerations	Action Column	8		There need not be a defined action for a COP. These parameters were deemed sufficiently important to warrant attention by the operator.
Plan/Assumption that all will be operated to exhaustion (simultaneously) and then regenerated?	14	Full-Scale SWIFT Facility Considerations	GAC Rows	8		Likely operation is in parallel.
It would seem a $\leq$ 0.5 gm/L would be the trigger or would it be $\geq$ 0.5?	14	Full-Scale SWIFT Facility Considerations	Monochloramine Residual Alarm Value	8		< added ahead of 0.5.
According to these ranges pH 2 or pH12 would be ok, but not in the neutral range?	14	Full-Scale SWIFT Facility Considerations	SWIFT Water pH – Alert and Alarm Values	8		Text adjusted
To be monitored in more detail elsewhere?	14	Regulatory Sampling Plan	1st paragraph "online analyzer"			Text adjusted.
Only monitored quarterly? Since bromate can be a significant issue as well as brominated THMs and HAAs, I would have expected more frequent analysis. (Monthly as THMs and HAAs are?)	26	Regulatory Sampling Plan	Bromide	10		These are minimum frequencies. Bromide and bromate will be monitored much more frequently, particularly during startup operations.
15-min averaged?	28	Regulatory Sampling Plan	1st footnote	10		Correct, 15 min averages.

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
Non-native?	8	Report Purpose	1, 2nd sentence			Adjusted nonsensical sentence to address “native” issue.
Confusing statement	8	Report Purpose	1, 2nd sentence			Statement revised to better express concept.
When Na-exchange capacity is >15% (of total CEC) this can be particularly problematic but may occur as low as 5%	9		Clay Particle Dispersion	2-1		Acknowledged – good comment, but No Action
Water	9	Mineral Dissolution and mobilization	1, last sentence			Acknowledged – corrected title.
Short-term	14	Physical Characterization Approach	1, 2nd sentence			Modified sentence to better pair short and long term with the individual test for the two comments.
Longer-term test	14	Physical Characterization Approach	1, 2nd sentence			Modified sentence to better pair short and long term with the individual test for the two comments.
Such as	14	Chemical Characterization Approach	1, 2nd sentence			Added “as”.
Not applicable	14	Chemical Characterization Approach	pH MDL	3-2		Added NA to table.
Not applicable	14	Chemical Characterization Approach	Temperature MDL	3-2		Added NA to table.
2nd time listed	15	Chemical Characterization Approach	Chloride	3-2		Removed second listing of chloride.
Way to high	15	Chemical Characterization Approach	Ortho phosphate	3-2		Adjusted MDL.
MDL is not defined. If it is method detection limit a couple parameters should be not applicable and many others can be easily detected below the value in the MDL column.	15	Chemical Characterization Approach	Noted at the bottom of the page			Defined MDL in notes for table
Water, mineral or both?	16	Groundwater Characterization	3rd sentence			Defined sample type (“water”)
No CEC analysis for aquifer mat’l. Why? Recharge water would contact aquifer mat’l more than conf. unit.	16	Mineralogical Laboratory Analysis	3, sentence starting “Samples originating from”			Provided explanation for not obtaining CECs in aquifer sands (lack of sample material).
according to	16	Aquifer Mineral and Clay Matrix Characterization Evaluation	1st bullet			Edited text.
?	16	Aquifer Mineral and Clay Matrix Characterization Evaluation	5th bullet			Attempted to clarify bullet.
?	16	Aquifer Mineral and Clay Matrix Characterization Evaluation	Last paragraph, 2nd last sentence starting with “The CEC results”			Attempted to better describe technique for projecting CEC values found in confining beds across aquifer sands.
Not in the reference SXN	17	Conventional Geochemical Analysis	2nd paragraph starting, “Piper and Stiff diagrams”, last sentence			Added citation in narrative and References
Deleted “A”	17	Conventional Geochemical Analysis	3rd paragraph, change reference from “et. Al” to “et. al”			Edited text.
Modeling also conducted with native GW and aquifer minerals to help decipher minerals controlling solubility of various metals and ligands.	18	Geochemical Modeling – Modeling approach	1st paragraph under Phase 1			Added the suggested sentence.

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
Will this be conducted experimentally as well?	18	Geochemical Modeling – Modeling approach	3rd bullet under Phase 2			Yes. We will subject core samples to adsorption testing in 2018. No action in this report.
Inserted "and"	19	Geochemical Modeling – Modeling approach	1st paragraph under Phase 3, inserted after "minerals"			Edited text.
Physical? Geochemical?	19	Geochemical Modeling – Modeling approach	1st paragraph under Phase 3, 1st bullet			Described condition affecting clay stability ("geochemical").
Seems to reflect low Na-EC (i.e. clay dispersion not an issue)	19	Geochemical Modeling – Modeling approach	1st paragraph under Phase 3, last three bullets			Acknowledged – good comment, but No Action needed.
Water chemistry suggests impact crater impacts	27	Aquifer Mineral and Clay Matrix Data	SWR-NP03[4] column heading	4-1		Acknowledged.
These temperatures are too high for the Potomac Aquifer. Should be only 10 to 15 degrees C	27	Aquifer Mineral and Clay Matrix Data	Temperature Row, 1st 5 columns	4-1		Temperatures accurate, measured with several instruments. No action.
Signif mn conc.	27	Aquifer Mineral and Clay Matrix Data	Manganese dissolved Row, 1st 5 columns	4-1		Acknowledged – No action necessary.
(cont.)	28	Aquifer Mineral and Clay Matrix Data	Added after Table name	4-1		Text edited.
Lower than other locations in the Potomac Aquifer (e.g. Norfolk's wells in Suffolk & Isle of Wight).	28	Aquifer Mineral and Clay Matrix Data	Fluoride row, 1st 5 columns	4-1		OK – will describe in txt
Total ortho P not consistent w/ U, M, LPA at locations I am familiar with	28	Aquifer Mineral and Clay Matrix Data	Orth-phospate row, "SWR_NPW1 24 Hr CRT 8/4/2016" column	4-1		Acknowledged.
(cont.)	29	Aquifer Mineral and Clay Matrix Data	Added after Table name	4-1		Text edited.
Why not after GAC or post – UV? Ionic makeup not likely to change substantially but lower TOC likely.	29	Aquifer Mineral and Clay Matrix Data	6th note after table	4-1		Samples were collected after UV – amended table note
Was an ion balance (Σ cationic charge = Σ anionic charge attempted?	29	Aquifer Mineral and Clay Matrix Data	Added at bottom of the page after Table	4-1		Yes. All analyses balanced within 5% difference
Iron and Mn in PA water is considerably higher than recharge.	34	Data Observations – Recharge Water Data Observations and Discussion - Carbon-based Recharge Water Observations and Discussion	5th bullet			Acknowledged. No action necessary
Comment for this value and the three above it: measured or calculated from a redox couple? Or calculated from ORP measurements	38	Data Observations – Recharge Water Data Observations and Discussion - Carbon-based Recharge Water Observations and Discussion	Packer Test – LPA row – Eh column	5-2		Added note to describe Eh calculated.
Was each layer screened with the same aquifer surf. Area? These #s seem to support that assumption.	39	Groundwater Data Observations and Discussion – Upper Potomac Aquifer Data Observations and Discussion	Contribution (%) column	5-3		We calculated percentage contribution by comparing transmissivity from 24 hour constant rate test in TW-1 to results of Packer Testing in each aquifer. No action needed in report
Should comment on low F measured in 3 depths and then high F for post 24-hr sample.	40	Groundwater Data Observations and Discussion – Upper Potomac Aquifer Data Observations and Discussion	6 bullet after table - Fluoride			Added sentence on origin of Fluoride. "The elevated value observed in the sample collected during the 24-hour constant rate aquifer test likely originated from the UPA."
Compare results to other Potomac Aquifer WQ	40	Groundwater Data Observations and Discussion	Noted at the bottom of the page			Regional WQ in Potomac aquifer

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
results?		– Upper Potomac Aquifer Data Observations and Discussion				will have little bearing on the results of the project at Nansemond. Though discussing differences seems interesting and academic, it is not considered for the purposes of this document.
Really? I guess it is not expected for anyone to read this table? (printed in portrait instead of landscape)	43	Lithology Data Observations and Discussion	Make sure table is in landscape when printed	5.4		Will format electronic document so that this table is in landscape.
And nowhere else? Interpretation?	48	Lithology Data Observations and Discussion	2nd paragraph, last figure in sentence "1,030 fbg"			Text edited to describe handling of siderite and pyrite despite their absence in laboratory results.
No results yet presented on exchange capacity.	48	Summary of Lithological Information	2nd paragraph			Acknowledged. Cation exchange capacity results appear below.
Easily could have done many ratios	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mixed Modeling**	1st sentence carried over from page 48, "1:1 ratio"			Addressed comment on mixing ratio. 1:1 usually produces the most conservative results.
A more soluble mineral could control solubility	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	2nd paragraph, 3rd sentence starting "Quartz"			Acknowledged, yet the analysis considered minerals common to the Potomac Aquifer system as seen in the PHREEQC simulations, identified in formation samples in the field, and mineralogic analysis by the lab. No action necessary in report.
Wat DO or Eh was set for model runs?	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	3rd paragraph, last sentence			Acknowledged. Described DO concentrations and Eh measurements employed in PHREEQC.
Sentence doesn't make sense	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	4th paragraph, 2nd to last sentence			Corrected sentence.
Has warming of the aquifer been considered?	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	4th paragraph, 2nd to last sentence			No. The more likely situation will involve colder water when treated wastewater is recharged in the winter.
Mineral solubility is also pressure dependent, has this been considered in chem equil calculations? (i.e. pressure at 1000 ft bgl)	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the bottom of the page			No. Pressures below 50 Bars should not influence mineral solubilities.
Mineral solubility is temperature dependent. Would thermal expansion have any positive/negative impacts? What have others practicing GW recharge observed?	49	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the bottom of the page			No. Injecting cold water during the winter will more likely reduce the intrinsic permeability of the aquifer, cause denser water to migrate along high permeable

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
						flowpaths, and slow down the rate of geochemical reactions. Considering these factors, colder water represents a more geochemically inert recharge. Presently, we don't have data on the range of recharge temperatures. So statements describing the effect of temperature on aquifer minerals is highly speculative. Presently, we have no evidence that temperatures will increase above temperatures in aquifer.
Has a transport option	50	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the top of the blank page			We did not employ the Transport function in PHREEQC for this evaluation
PHREEQC Does have a kinetic capability, but not sure it has been used here.	50	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the top of the blank page			We did not apply the Kinetic function in PHREEQC. But will employ it when we obtain actual recharge data for which we can calibrate rate constants used in Kinetic simulations.
Was O2 modeled at a constant concentration (assuming slow kinetics of dissolution/oxidation of FeCO3)	50	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the top of the blank page			No. The simulations involved exposing siderite to a range of DO concentrations. Will modify text to better highlight DO concentrations.
Do modeled as a fixed conc. $\frac{15\ mg\ O_2}{L} \cdot \frac{mole\ O_2}{32{,}000\ mg\ O_2} \cdot \frac{4e^-}{mole\ O_2}$ $\frac{300\ mg\ Fe}{L}$	50	Mineral Dissolution/Precipitation Evaluation - Evaluation Results Mixing Between Recharge Water and Native Groundwater – **Mineral Precipitation/Dissolution Evaluation**	Noted at the top of the blank page			Yes. No action necessary.
Added "such"	53	Summary of Recharge Water/Groundwater Mixing Modeling Results	1st bullet - Added after "present"			Text edited.
Added "will all be understated"	53	Summary of Recharge Water/Groundwater Mixing Modeling Results	1st bullet - After "siderite"			Text edited.
Deleted "which"	53	Summary of Recharge Water/Groundwater Mixing Modeling Results	1st bullet - After "understated"			Text edited.
Added "preventing"	53	Summary of Recharge Water/Groundwater	1st bullet - After "understated"			Text edited.

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
		Mixing Modeling Results				
Reflect the conditions that would be governing the aquifer.	53	Summary of Recharge Water/Groundwater Mixing Modeling Results	Last sentence after 2nd bullet starting "Therefore,"			Added several sentences on running Transport and Kinetic simulations.
PHREEQC was run as a purely chem. equi model and does capture kinetics. The out put from model runs may not ~~reflect the conditions that would be governing~~ a	53	Summary of Recharge Water/Groundwater Mixing Modeling Results	Last sentence after 2nd bullet starting "Therefore," – handwritten note illegible			Added several sentences on running Transport and Kinetic simulations.
No it doesn't – replace with hydrolyzes	53	Siderite Dissolution (Iron Mobilization Effect)	1st sentence, "further oxidizes"			Edited text to "hydrolyzes".
Deleted "s"	53	Siderite Dissolution (Iron Mobilization Effect)	2nd paragraph, 1st sentence, deleted from "recharges"			Acknowledged. As we are not considering reaction kinetics here, No Action is required
Added "water"	53	Siderite Dissolution (Iron Mobilization Effect)	2nd paragraph, 1st sentence, added after "recharge"			Text edited.
Deleted "and"	53	Siderite Dissolution (Iron Mobilization Effect)	2nd paragraph, last sentence, deleted after HFO			Text edited.
Rxn w/o – FEOOH (or similar) would likely be quick	53	Siderite Dissolution (Iron Mobilization Effect)	3rd paragraph			Acknowledged. As we are not considering reaction kinetics here, No Action is required
What is the rxn (decomposition/dissolution) of siderite? $4FeCO_3 + O_2 \rightarrow 4Fe(II) + O_2 \rightarrow 4Fe^{3+}$	53	Siderite Dissolution (Iron Mobilization Effect)	3rd paragraph			Displayed and discussed reaction.
But the aquifer minerals may have a high capacity (or not) for exchange of H+ for cations on exchange sites.	54	Pyrite Oxidation	2nd paragraph "Modeling"			Acknowledged. Added sentence, describing potential buffering mechanism
Run experimentally to confirm?	54	Pyrite Oxidation	2nd paragraph last sentence			Acknowledged. May consider batch experiments if future sampling encounters pyrite.
There is a kinetic component of every	55	Arsenic Mobilization Effect	2nd paragraph/sentence after formaula			Acknowledged. No action required
Changed "et. Al" to "et. al"	55	Arsenic Mobilization Effect	3rd paragraph, Jones reference			Edited text.
Was XRD analysis capable of identifying As incorporation into pyrite?	55	Arsenic Mobilization Effect	3rd paragraph, 2nd to last sentence "pyrite"			Evidence of arsenic did not appear in XRD, or x-ray, energy dispersive (EDX) analysis.
It was just stated as 5 to 20 mg/L DO. Not it is just 5 mg/L?	56	Arsenic Mobilization Effect	1st paragraph, last part of last sentence			Corrected range.
What did EDX show?	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts -	1st paragraph			Addressed with several sentences on presence of arsenic. "Even through energy dispersive, x-ray analysis (EDX) showed no evidence of arsenic in formation samples, conservative analysis requires considering that arsenic is present somewhere in the aquifer. Considering the potential for arsenic occurring in reactive minerals like pyrite, recharge water adjustments can be made to

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
						prevent the mobilization of the constituent."
Deleted "of"	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence, deleted after "raises"			Edited text
Added "water pH"	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence, added after "recharge"			Edited text
Increasing the pH will lower the Fe(III) solubility and increase the rate of Fe(II) → Fe(III) oxidation	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence			Acknowledged. Added sentence.
Not shown or discussed previously.	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence			Acknowledged. The report discusses iron solubility in the context of mitigating mineral dissolution.
FeS2 or FeC03?	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence			Acknowledged. Wrote out mineral names
I'm not sure I would call this buffering.	56	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph, 2nd sentence			Acknowledged. Changed buffering to diminishing.
As sorption on HFO (and other adsorbents) is competitive. At pH7 As(V) is present in equal concentrations. As H2As04 and Has042 both forms clearly anionic, aqueous silicate, phosphate, fluoride, sulfate can compete for sites and varying concentrations of these constituents can cause adsorption/desorption of sorbed As.	57	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)			Figure 5-7	True statement. Acknowledged, but does not really describe figure. No action needed
Changed "completed" to "completely"	57	Mitigation Approaches for Mineral Dissolution and Precipitation Impacts - Mitigating Pyrite Oxidation and Siderite Dissolution (Iron Mobilization)	1st paragraph,3rd sentence			Edited text.
Not in the reference sxn.	57	Mitigating Pyrite Oxidation (Arsenic Mobilization)	Last reference on page			Added.
What is this? An internet search cannot find it and it wasn't described earlier.	58	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	2nd paragraph, after last bullet point "WATERPRO"			Added citation in narrative and references for Water!PRO.
Shown only here	58	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	Last paragraph			Edited the narrative to describe the simulation results which we are discussing here.
Does this modeling include the oxidation of FeC03(s) and FeS2(s) or just the composition of the recharge water?	58	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	Last paragraph			The modeling involved exposing pyrite and siderite to a range of DO concentrations at a set alkalinity.

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
What equilibrium constant (i.e., KSO) values are being used in these calculations? They are likely default values in the PHREEQC database, but they should be included here. Also, what temperature is being assumed?	59	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)		5-9		Default values in the WATEQ4f database were employed. The input temperature of the BAC and RO samples were used for input to PHREEQC.
Amorphouse Fe(OH)3(8)	59	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	SI-HFO column	5-9		Changed column heading.
How is alk addition modeled?	59	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	2nd paragraph after table			Alkalinity was modeled as an alkalinity concentration, while varying the DO concentration added sentence describing inputting alkalinity in PHREEQC
As a CT1C03 increase?	59	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	2nd paragraph after table			Same as comment above.
Are the solubility products being corrected for temperature?	59	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)	3rd paragraph after table			PHREEQC corrects the solubility products for temperature.
What are all these pts between initial pH7.8 and final pH? Do they relate to some time step?	60	Aquifer Matrix Passivation and Precipitation Management (pH and Buffering Alkalinity)			5-9	The points denote pH and alkalinity at varying DO concentrations. DO concentrations ranged from 5 to 20 mg/L, each reaction producing an alkalinity and pH.
Cation exchange would be pretty difficult with this large, polymeric molecule.	61	Mitigation Approaches for Clay Structure Fragmentation Impacts	2nd paragraph			Added sentence on preventing clay dispersion.
Could be a lot clearer	62	Mitigation Approaches for Clay Structure Fragmentation Impacts			5-10	Acknowledged. Will obtain a more clear figure.
Why only confining layers? CEC too difficult to determine (low) in the water bearing/conveying sections of the aquifer?	63	Mitigation Approaches for Clay Structure Fragmentation Impacts		5-10		Yes. CEC analysis proved difficult on the sand samples, producing inaccurate results.
An odd, confusing what to display these data	65	Clay Particle Dispersion Evaluation			5-12	Acknowledged. Attempted to show in different manner, rejected by other reviewers. No further action.
Not in reference sxn	68	Impact of Changing Clay Structure	3rd paragraph starting “More important”, reference Honig and Mul			Added to references.
Incomplete reference in ref sxn.	68	Regional Anecdotal Example	1st paragraph, reference Brown and Silvey, 1977			Edited text.
Not in reference sxn	69	Treating the LPA with a Calcium Salt Flush	2nd paragraph, reference Breeuwsma (1986)			Added to references.
Changed reference “et. Al” to et. al”	72	Treating the LPA with a Calcium Salt Flush	1st paragraph, reference Khilar			Edited text.
Not in reference sxn	72	Treating the LPA with a Calcium Salt Flush	1st paragraph, reference Khilar			Added to references.
Probably small	72	Treating the LPA with an Aluminum Chloride Flush	1st paragraph, 4th sentence			Acknowledged – No Action
True, but how does this comport with the claim on p 5-29. The makeup (monomeric/polymeric fraction,	72	Treating the LPA with an Aluminum Chloride Flush	1st paragraph,2nd sentence			Added statement on speciating aluminum in conditioning water.

G. Schafran Comments on Attachment D - SWIFT UIC Inventory Information Package

Comments/Questions	Page	Section	Paragraph	Table	Figure	Responses to Comments
specific aqueous complexes) would be a function of the solution concentration and other factors when an A1C13 was partially hydrolyzed. Will an attempt be made to characterize actual Al species?						“Considering the small aluminum radius, future testing will involve analyzing for aluminum species, an important consideration for developing the desired hydroxy-aluminum molecule without increasing turbidity of the water used for conditioning clays.”
Ionic strength	75	Selecting the Recharge	2nd sentence			Acknowledged. Included in acronym section.
Changed reference “et. Al” to et. al”	75	Selecting the Recharge	2nd paragraph, reference Konikow			Edited text.
Missing	75	Selecting the Recharge	2nd paragraph, reference Konikow			Added to references.
Not in the acronym and abbreviations sxn on page v	75	Selecting the Recharge	3rd paragraph, “PMCL”			Added.
Is this supposed to be primary maximum contaminant limit? There is no PMCL for pH. Secondary MCL is pH 6.5-8.5 range .	75	Selecting the Recharge	3rd paragraph, “PMCL”			Corrected text.
Typically ionic strength is written out	76	Selecting the Recharge	1st paragraph			Included in acronym section.
NaOH or Na2C03 with aeration. Aeration alone won’t get you an alkalinity and buffering intensity.	76	Selecting the Recharge	2nd paragraph			Corrected statement.
Add “Brown and Silvey” to reference list	78	References				Added.

HRSD

January 22, 2018

Transmitted via email: gschafra@odu.edu

Gary Schafran, PhD
Department of Civil and Environmental Engineering
Old Dominion University

Dear ~~Dr. Schafran~~: Gary

Thank you for investing your time and expertise in the review of the technical documents supporting HRSD's submission for authorization to operate its recharge well at the SWIFT Research Center (SWIFTRC). Your comments and suggested edits improved the completeness, accuracy and clarity of the package. We have addressed your comments in the attached tables. If you have any questions regarding our responses, please let us know.

We appreciate your support of the SWIFT program and look forward to continued partnering in research to better understand and protect the health of the aquifer system.

Sincerely,

Ted

Ted Henifin, P.E.
General Manager